62ND ANNUAL FUZE CONFERENCE

Fuzing Innovations for Tomorrow's Weapons

May 13 – 15, 2019 | Buffalo, NY | NDIA.org/Fuze19

TABLE OF CONTENTS

WHO WE ARE

The National Defense Industrial Association is the trusted leader in defense and national security associations. As a 501(c)(3) corporate and individual membership association, NDIA engages thoughtful and innovative leaders to exchange ideas, information, and capabilities that lead to the development of the best policies, practices, products, and technologies to ensure the safety and security of our nation. NDIA's membership embodies the full spectrum of corporate, government, academic, and individual stakeholders who form a vigorous, responsive, and collaborative community in support of defense and national security. NDIA is proud to celebrate 100 years in support of our warfighters and national security. The technology used by today's modern warfighter was unimaginable 100 years ago. In 1919, BG Benedict Crowell's vision of a collaborative team working at the intersection of science, industry, government and defense began what was to become the National Defense Industrial Association. For the past century, NDIA and its predecessor organizations have been at the heart of the mission by dedicating their time, expertise and energy to ensuring our warfighters have the best training, equipment and support. For more information visit **NDIA.org**

LEADERSHIP

Roy Streetz
Fuze Committee Chair

Thomas Harward
Fuze Committee Vice Chair

Nassir Alaboud
Fuze Committee Secretary

FUZE MUNITIONS

WHO WE ARE

The purpose of the Fuze Section shall be to promote an open exchange of technical information among government and industry technical personnel, and to identify and address changes in standards, guidance, policy, and organizational functions that impact the development, production, and performance of fuzes.

WELCOME TO THE 62ND ANNUAL FUZE CONFERENCE

On behalf of the NDIA Fuze Conference Steering Committee Members and the NDIA, I would like to welcome you to the 62nd Annual NDIA Fuze Conference. This international conference brings together the work of the top professionals in the fuzing industry from government, private industry, and academia; and provides an opportunity for the exchange of the latest research and development on fuzing, with the common goals of improving safety, capability, and reliability for our warfighters. While the history of fuzing dates back several hundred years, and the advances in technology have been significant over that time, new challenges continue to emerge. Through the ongoing passionate work of the authors, presenters, sponsors, and attendees at this conference and across our worldwide defense industry, these challenges will be overcome, resulting in safer, more reliable fuzes being fielded to our warfighters.

Roy Streetz
Chair
NDIA Fuze Committee

Vice President Advanced Electronic Systems
Excelitas Technologies Corporation

SCHEDULE AT A GLANCE

MONDAY, MAY 13

Registration & Opening Reception
5:00 – 6:00 pm

TUESDAY, MAY 14

Registration
7:00 am – 5:00 pm

Networking Continental Breakfast
7:00 – 8:00 am

Welcome & Keynote Speaker
8:00 – 8:45 am

General Session
8:45 – 11:45 am

Networking Break
10:00 – 10:30 am

Harry Diamond Fuzing Excellence Award Presentation
11:45 am – 12:00 pm

Networking Lunch
12:00 – 1:00 pm

Concurrent Breakout Sessions
1:00 – 3:00 pm

Networking Break
3:00 – 3:20 pm

Concurrent Breakout Sessions
3:20 – 5:00 pm

Grand Reception
Big Ditch Brewing Company
5:30 – 7:00 pm

WEDNESDAY, MAY 15

Registration
7:00 am – 4:20 pm

Networking Continental Breakfast
7:00 – 8:00 am

Concurrent Breakout Sessions
8:00 – 10:00 am

Networking Break
10:00 – 10:20 am

Concurrent Breakout Sessions
10:20 am – 12:00 pm

Networking Lunch
12:00 – 1:00 pm

Concurrent Breakout Sessions
1:00 – 3:00 pm

Networking Break
3:00 – 3:20 pm

Concurrent Breakout Sessions
3:20 – 4:20 pm

THURSDAY, MAY 16

Tour of PCB Piezotronics, Inc.
PCB Piezotronics Headquarters
8:30 – 10:30 am

EVENT INFORMATION

LOCATION

Hyatt Regency Buffalo Hotel
Two Fountain Plaza
Buffalo, NY 14202

Big Ditch Brewing Company
55 E Huron St
Buffalo, NY 14203

PCB Piezotronics, Inc.
3425 Walden Avenue
Depew, NY 14043

EVENT WEBSITE

NDIA.org/Fuze19

EVENT THEME

Fuzing Innovations for Tomorrow's Weapons

WIFI

Network: Hyatt Meeting
Password: NDIA

INTERACTIVE KIOSK

We invite attendees to learn about NDIA's 100 year history through an interactive touchscreen.

ATTIRE

Civilian: Business casual
Military: Uniform of the day

SURVEY AND PARTICIPANT LIST

You'll receive via email a survey and list of attendees (name and organization) after the conference. Please complete the survey, which helps make our event even more successful in the future.

EVENT CONTACT

General Event
Reneé Despot
Manager, Meetings
(703) 247-2599
rdespot@ndia.org

Agenda
Loey Bleich
Program Manager
(703) 247-2575
lbleich@ndia.org

PLANNING COMMITTEE

Roy Streetz
Committee Chair

Nassir Alaboud
Ray Ash
Ed Cooper
Chris DeWitt
Mark Etheridge
Frank Fairchild
Lawrence Fan
Doug Harms
Thomas Harward
Robert Hertlein
Ken Kelly
Bill Kurtz
Homesh Lalbahadur
David Lawson
Byron Lee
Jim Lemister
Telly Manolatos
Bob Metz
Barry Neyer
Eric Roach
Perry Salyers
James Sharp
Don Shutt
Martin Tanenhaus

SPEAKER GIFTS

In lieu of speaker gifts, a donation is being made to the Fisher House Foundation.

HARASSMENT STATEMENT

NDIA is committed to providing a professional environment free from physical, psychological and verbal harassment. NDIA will not tolerate harassment of any kind, including but not limited to harassment based on ethnicity, religion, disability, physical appearance, gender, or sexual orientation. This policy applies to all participants and attendees at NDIA conferences, meetings and events. Harassment includes offensive gestures and verbal comments, deliberate intimidation, stalking, following, inappropriate photography and recording, sustained disruption of talks or other events, inappropriate physical contact, and unwelcome attention. Participants requested to cease harassing behavior are expected to comply immediately, and failure will serve as grounds for revoking access to the NDIA event.

AGENDA

MONDAY, MAY 13

5:00 – 6:00 pm

REGISTRATION
GRAND BALLROOM FOYER

Sponsored by L3 Defense Electronic Systems

5:00 – 6:00 pm

NETWORKING OPENING RECEPTION
GRAND BALLROOM FOYER

Sponsored by L3 Defense Electronic Systems

TUESDAY, MAY 14

7:00 am – 5:00 pm

REGISTRATION
GRAND BALLROOM FOYER

Sponsored by L3 Defense Electronic Systems

7:00 – 8:00 am

NETWORKING CONTINENTAL BREAKFAST
GRAND BALLROOM FOYER

Sponsored by JUNGHANS Defence

SESSION 1 – WELCOME, ADMIN REMARKS & KEYNOTE ADDRESS

8:00 – 8:05 am

INTRODUCTION & ADMIN REMARKS
GRAND BALLROOM ABC

Roy Streetz
Chair, NDIA Fuze Committee; VP Advanced Electronic Systems, Excelitas Technologies Corporation

8:05 – 8:15 am

NDIA OPENING REMARKS
GRAND BALLROOM ABC

MG James Boozer, USA (Ret)
Executive Vice President, National Defense Industrial Association

8:15 – 8:45 am

KEYNOTE SPEAKER
GRAND BALLROOM ABC

Col Gary R. Charlton II, USAF
Commander 107th Attack Wing, New York Air National Guard

SESSION 2 – U.S. GOVERNMENT SCIENCE, TECHNOLOGY & ACQUISITION

Thomas Harward
Raytheon
Session Chair

Bob Metz
PCB Piezotronics, Inc.
Session Assistant

8:45 – 9:10 am

ARMY S&T STRATEGY
GRAND BALLROOM ABC

Gene Henderson
U.S. Army CCDC Aviation & Missile Center

9:10 – 9:35 am

ARMY S&T STRATEGY
GRAND BALLROOM ABC

Charles Robinson
U.S. Army CCDC Armaments Center

9:35 – 10:00 am

NAVY S&T STRATEGY
GRAND BALLROOM ABC

Jason Koonts
NSWC Dahlgren

10:00 – 10:30 am

NETWORKING BREAK
GRAND BALLROOM FOYER

Sponsored by PACSCI EMC

10:30 – 10:50 am

AIR FORCE S&T STRATEGY
GRAND BALLROOM ABC

George Jolly
Technical Advisor, Air Force Research Laboratory/RWMF

10:50 – 11:10 am

SANDIA NL CAPABILITIES & MISSION
GRAND BALLROOM ABC

Adam Church
Manager, 2627 Advanced Fuzing Technology, Sandia National Laboratories

11:10 – 11:30 am

OSD PERSPECTIVE/FUZE IPT
GRAND BALLROOM ABC

Lawrence Fan
JFTP Manager, Naval Surface Warfare Center - Indian Head Division

11:30 – 11:45 am

JOINT FUZE TECHNOLOGY PROGRAM (JFTP)
GRAND BALLROOM ABC

Tim Tobik
Air Force Research Laboratory

11:45 am – 12:00 pm

HARRY DIAMOND FUZING EXCELLENCE AWARD PRESENTATION

GRAND BALLROOM ABC

Roy Streetz
Chair, NDIA Fuze Committee; VP Advanced Electronic Systems, Excelitas Technologies Corporation

Presented to:
Philip T. Gorman, Jr.
Lead Associate, Booz Allen Hamilton

12:00 – 1:00 pm

NETWORKING LUNCH

GRAND BALLROOM FOYER

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CONCURRENT BREAKOUT SESSIONS

SESSION 3A – OPEN SESSIONS

GRAND BALLROOM EFG

Bob Metz
PCB Piezotronics, Inc.
Session Chair

Mark Etheridge
U.S. Army AMRDEC
Session Assistant

1:00 – 1:20 pm

Guidelines for Implementing a Low Voltage Command Arm Distributed Fuzing System

21801

Mark Etheridge
Electrical Engineer, U.S. Army CCDC Aviation & Missile Center

1:20 – 1:40 pm

Advanced Modeling and Analysis in the Design of Next Generation Accelerometers for Fuzing Applications

21774

David Ort
R&D Engineer, PCB Piezotronics, Inc.

1:40 – 2:00 pm

Effectiveness of 40mm High Velocity Air Burst Ammunition

21770

Cemil Yilmaz
Lead Engineer, ASELSAN, Inc.

2:00 – 2:20 pm

Calibration and Acceptance Tests for Accelerometers Used in Severe Shock Applications

21783

Jeffrey Dosch
Technical Director, PCB Piezotronics, Inc.

SESSION 3B – CLOSED SESSIONS

GRAND BALLROOM ABC

Homesh Lalbahadur
U.S. Army ARDEC
Session Chair

Nassir Alaboud
Lockheed Martin
Session Assistant

1:00 – 1:20 pm

Preparing EOD for Fuzing Innovations

21766

Justin Welling
Lead Systems Engineer, USAF AFLCMC/EBDZ

1:20 – 1:40 pm

Evaluation of Embedded Fuze Components in Explosives

21848

Tiffany Hatcher
1st Lt, U.S. Air Force, AFRL/RWMF

1:40 – 2:00 pm

Fuzing Components in High-G Shock Regime

21871

Joshua Dye
Electrical Engineer, Sandia National Laboratories

2:00 – 2:20 pm

M1156 Precision Guidance Kit (PGK) Multi-Option Fuze Transition to Production

21804

Nathan Noble
Senior Principal Manufacturing Engineer, Northrop Grumman Innovation Systems

2:20 – 2:40 pm

Microwave Interferometry to Investigate Transition Phenomena Inside Detonators
21895

Alexandre Lefrancois
Engineer, CEA Gramat

MEMSAD – Maturing the Technology
21805

Lynne Rider
U.S. Army CCDC Armaments Center

2:40 – 3:00 pm

Close-Air-Support with <190 Rounds… A Practical Approach
21776

Lauren Schumacher
Self-Graduate Fellow, The University of Kansas

Test Observed Considerations for Embedded Smart Fuzing of Penetrating Munitions
21874

Alma Oliphant
Principal Engineer, Applied Research Associates

3:00 – 3:20 pm

NETWORKING BREAK
GRAND BALLROOM FOYER

Sponsored by PACSCI EMC

CONCURRENT BREAKOUT SESSIONS

Continued

SESSION 3A - OPEN SESSIONS
GRAND BALLROOM EFG

SESSION 3B - CLOSED SESSIONS
GRAND BALLROOM ABC

3:20 – 3:40 pm

Novel Approach for Fuze Safety Design and Requirements in Drone Based Weapon Systems
21782

Tal Leibovich
Head of Technology - Development Section, IDF

Proximity Sensors For Hypersonic Applications
21853

Kristin DeWeese
Systems Engineering Manager, L3 Technology

3:40 – 4:00 pm

Unmanned Systems Safety Precepts
21838

Jeffrey Fornoff
Senior Engineer, U.S. Army CCDC Armaments Center

Tail Kit Impact Environment Analysis and Ground Test Design
21873

Alma Oliphant
Principal Engineer, Applied Research Associates

4:00 – 4:20 pm

Lithium Battery Innovations for Projectile Munitions
21767

Paul Schisselbauer
Director of Engineering, EnerSys Advanced Systems

Embedded Fuze Forward Assembly Cannon Test
21885

Mark Mlejnek
Electrical Engineer, L3 Fuzing & Ordnance Systems

4:20 – 4:40 pm

Exploring High-Strain-Rate Deformation of Microscale Planar Metallic Materials using Customized Taylor Anvil Impact Test
21840

Jeffrey Smyth
Mechanical Engineer, U.S. Army CCDC Armaments Center

Advanced Material Model Development and Setback Sensing
21883

Bill Bartinelli
Mechanical Engineer, L3 Fuzing & Ordnance Systems

4:40 – 5:00 pm

FMCW (Frequency Modulated CONTINUOUS WAVE) Proximity Technology with Advance EM Insensitive Features
21781

Luis Abad
Product Manager - Fuze Systems, Expal Systems

Characterizing Embedded Fuzing Environments with Non-Linear Viscoelastic Modeling
21852

Shane Curtis
Staff Member, Sandia National Laboratories

5:30 – 7:00 pm

NETWORKING GRAND RECEPTION
BIG DITCH BREWING COMPANY
55 E HURON ST, BUFFALO, NY 14203

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WEDNESDAY, MAY 15

7:00 am – 4:20 pm

REGISTRATION
GRAND BALLROOM FOYER

Sponsored by L3 Defense Electronic Systems

7:00 – 8:00 am

NETWORKING CONTINENTAL BREAKFAST
GRAND BALLROOM FOYER

CONCURRENT BREAKOUT SESSIONS

SESSION 4A – OPEN SESSIONS
GRAND BALLROOM EFG

Eric Roach
Lockheed Martin
Session Chair

Telly Manolatos
Electronics Development Corp.
Session Assistant

SESSION 4B – CLOSED SESSIONS
GRAND BALLROOM ABC

Byron Lee
Northrop Grumman Innovation Systems
Session Chair

Jim Sharp
Naval Surface Warfare Center Dahlgren
Session Assistant

8:00 – 8:20 am

DoD MEMS Fuze Explosive Train Evaluation and Enhancement
21865

David Muzzey
Chemical Engineer, NSWC IHEODTD

Advanced Fireset Electronics and Custom Packaging for Extremely High Shock Survivability
21753

Ron Knobler
Director of Engineering, McQ, Inc.

8:20 – 8:40 am

SPACIDO 1D Course-Correction Fuze
21831

Benjamin Campion
Programme Manager, JUNGHANS Defence

Electrical Transmission Line Replacement for Det-Cords in Flight Termination Systems
21761

Dustin Atwood
Mechanical Engineer, Naval Air Warfare Center Weapons Division

8:40 – 9:00 am

Guided Munitions for Aerial Gunnery; Increased Mission Effectiveness and Large Cost Savings
21775

Lauren Schumacher
Self-Graduate Fellow, The University of Kansas

Neyer Testing Results for MEMS S&A Bridgewires
21762

Charles Romaniello III
Mechanical Engineer, U.S. Army CCDC Armaments Center

9:00 – 9:20 am

Prototyping Fuze Electronics for High Reliability Manufacturing
21772

Stephen Redington
Sr. Engineer, U.S. Army CCDC Armaments Center

Matt Sargent
U.S. Army CCDC Armaments Center

M550 Safe & Arm Redesign
21842

Jason Sweterlitsch
Fuze Engineer, U.S. Army CCDC Armaments Center

9:20 – 9:40 am

Numerical Simulations at the Core of Acceleration Testing Expertise
21841

Paul Deconinck
R&D Manager, Thiot Ingenierie

Current Controlled Solidtron Characterization and Testing Results
21887

Jeff Gardner
Electrical Engineer, L3 Fuzing & Ordnance Systems

9:40 – 10:00 am

Providing Continued DSU-33D/B Viability
21855

Dave Liberatore
Sr. Program Manager, Northrop Grumman Innovation Systems

Advanced Nano-structuring and Enhanced Performance of Thermal Battery Cathode Materials
21780

Giuseppe Di Benedetto
U.S. Army CCDC Armaments Center

10:00 – 10:20 am

NETWORKING BREAK
GRAND BALLROOM FOYER

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CONCURRENT BREAKOUT SESSIONS

Continued

SESSION 4A - OPEN SESSIONS
GRAND BALLROOM EFG

SESSION 4B - CLOSED SESSIONS
GRAND BALLROOM ABC

10:20 – 10:40 am

FMU-139D/B Qualification and Production for Operation Use
21856

Scott Pfeiffer
Program Director, Fuzing & Electronic Integration, Northrop Grumman Innovation Systems

Fuze Enhanced Airburst Response for Medium Caliber Munition
21757

Alexander Neeb
Fuze Engineer, U.S. Army CCDC Armaments Center

10:40 – 11:00 am

Safety Logic Dilemmas for Loitering Unmanned Ground Vehicle (UGV) Munitions
21877

Shay Sas
Fuze Engineer, RAFAEL Advanced Defense Systems, Ltd.

EFI Fire Pulse Delay Circuit
21756

Michael Haddon
Engineer, NAWCWD

11:00 – 11:20 am

Drop Testing of LIGA MEMS Parallel Beam, Bi-Stable Latching Metallic Mechanisms
21839

Kevin O'Connor, Jr.
Mechanical Engineer, U.S. Army CCDC - Armaments Center Fuze Division

Kevin Aghaei
Mechanical Engineer, U.S. Army CCDC - Armaments Center Fuze Division

Target Scene Generator
21863

Dexter Cook
U.S. Army CCDC Armaments Center

11:20 – 11:40 am

Sensitivity Prediction of Exploding Foil Initiators
21768

Qingchou Chen
Engineer of Institute of Chemical Materials, China Academy of Engineering Physics

Optical Fuze Programmer Project Update
21844

Steve Guerrera
VP of Engineering, Creative Microsystems Corporation

11:40 am – 12:00 pm

Innovative Developments in Carbon Cathode Matrix Materials for Li/SOCl2 Reserve Batteries Used in Artillery Projectiles
21851

Brett Barclay
Design Engineer, EnerSys Advanced Systems

Material Properties Comparison between Additive Manufactured and Machined Parts
21886

Bryan Driskell
Mechanical Engineering Manager, L3 Fuzing & Ordnance Systems

12:00 – 1:00 pm

NETWORKING LUNCH
GRAND BALLROOM FOYER

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CONCURRENT BREAKOUT SESSIONS

SESSION 5A – OPEN SESSIONS
GRAND BALLROOM EFG

Perry Salyers
L3 Defense Electronic Systems
Session Chair

Jim Lemister
Pacific Scientific Energetic Materials
Session Assistant

SESSION 5B – CLOSED SESSIONS
GRAND BALLROOM ABC

Doug Harms
NNSA's National Security Campus
Session Chair

Bob Metz
PCB Piezotronics, Inc.
Session Assistant

1:00 – 1:20 pm	**Hardened, Compact and Fast: Adaptive Flight Control Actuators for Guided Hard-Launched Munitions** 21779 Dr. Ron Barrett-Gonzalez Professor of Aerospace Engineering, Director of the Adaptive Aerostructures and Aircraft Design Laboratories, The University of Kansas	**Wireless Power Transmission for Distributed Multi-Point Fuzing Applications** 21870 Joshua Dye Electrical Engineer, Sandia National Laboratories
1:20 – 1:40 pm	**A Historical Review of US Aerial Engagements: 1946-Present** 21777 Lauren Schumacher Self-Graduate Fellow, The University of Kansas	**ARDEC Fuze S&T** 21854 Evan Young U.S. Army CCDC Armaments Center
1:40 – 2:00 pm	**A Structured Approach to Fuze Technology Refresh** 21902 Vince Matrisciano R&D Program Coordinator, Joint PEO Armaments & Ammunition	**High Voltage Switch Development** 21861 Paul Heffernan DOE KC-NSC (Honeywell FM&T)
2:00 – 2:20 pm	**High Quality, High Throughput Neutron Radiography using Accelerator Based Neutron Generators** 21857 Brad Bloomquist Director of Business Development, Phoenix, LLC	**Small-Scale Testing of Electronic Components in Shock Loading** 21904 Vasant Joshi Scientist, NSWC
2:20 – 2:40 pm	**Survivability and Reliability of Silicon MEMS Components** 21868 Caitlyn May Mechanical Engineer, NSWC IHEODTD	**Ground Testing Suite to Reduce Risk for Fuzes in Hard Target Penetrators** 21872 Ericka Amborn Senior Engineer, Applied Research Associates
2:40 – 3:00 pm	**Equipment for Characterization of an EFI according to STANAG 4560 – A Generic STANAG Comes Alive…** 21812 Christian Euba Systems Engineer, TDW (MBDA)	**Missile ESAD Enhancements** 21859 Eric McDonough Northrop Grumman Innovation Systems
3:00 – 3:20 pm	**NETWORKING BREAK** GRAND BALLROOM FOYER	Sponsored by PCB PIEZOTRONICS MTS SYSTEMS CORPORATION

CONCURRENT BREAKOUT SESSIONS

Continued

SESSION 5A – OPEN SESSIONS
GRAND BALLROOM EFG

SESSION 5B – CLOSED SESSIONS
GRAND BALLROOM ABC

3:20 – 3:40 pm

Development and Testing of Setback Locks for High Reliability in DPICM-XL
21765

Laura Ostar-Exel
Mechanical Engineer, U.S. Army CCDC Armaments Center

Tailored EFIs for Enhanced Safety & Performance
21769

Nate Sanchez
R&D Engineer, Los Alamos National Laboratory

3:40 – 4:00 pm

Li-Ion Battery for FTS and Telemetry Application
21771

Dmitry Molchanov
Electrical Engineering Manager, EnerSys

Antifuse Obsolescence Mitigation in ESAD Applications: Analysis of High Shock, Acceleration and Vibration Effects on Safety Critical Logic Devices
21884

Nicholas Adams
Engineering Supervisor, L3 Fuzing & Ordnance Systems

4:00 – 4:20 pm

Development of Electronics for DPICM-XL CMRT
21837

Andrew Warne
Chemical Engineer, U.S. Army CCDC Armaments Center

Smart Distributed Embedded Fuzing: Current and Future Research Directions
21875

Curtis McKinion
Mechanical Engineer, Air Force Research Laboratory

4:20 pm

ADJOURN

THURSDAY, MAY 16

8:30 – 10:30 am

FACILITY TOUR OF PCB PIEZOTRONICS, INC.
PCB PIEZOTRONICS, INC.
3425 WALDEN AVENUE, DEPEW, NY 14043

*Separate registration required to attend.

KEYNOTE BIOGRAPHY

COL GARY R. CHARLTON II, USAF

Commander
107th Attack Wing, New York Air National Guard

Col. Gary R. Charlton II is the commander, 107th Attack Wing, New York Air National Guard, Niagara Falls Air Reserve Station, Niagara Falls, NY. He commands the 107th Attack Wing, encompassing operations, medical, and mission support group functions as well as, two geographically separated units. He is responsible for the deployment and employment of assigned personnel and equipment to ensure these assets are available to support all state and national requirements.

Charlton enlisted in the New York Air National Guard in May 1990 and served as a fuels systems technician. He graduated from Columbia College in 1995 earning a Bachelor of Arts degree in psychology. He then commissioned in 2000 and attended undergraduate pilot training in 2001. Charlton completed initial F-16 qualification training in 2002 and served as an F-16C pilot flying with the 138th Fighter Squadron, Hancock Field, NY. He has held the positions of flight, detachment and squadron commander of the 138th Fighter Squadron; as well as 107th Operations Group commander. Prior to his current assignment, he was the vice commander of the 107th Attack Wing, Niagara Falls, NY.

A combat veteran, Charlton served seven combat deployments, three while enlisted, Operations Desert Shield and Storm, and Northern Watch, and four additional deployments flying F-16C combat missions in Operations Iraqi and Enduring Freedom. He is a command pilot with over 3,200 flying hours in the T-37, T-38A, T-38C, F-16C/D, MQ-1, and MQ-9

AWARDEE BIOGRAPHY

PHILIP T. GORMAN, JR.

Lead Associate
Booz Allen Hamilton

March 2019 – Present: Booz Allen Hamilton Senior Lead Technologist, Ordnance. Fuzing Systems: 36 years' experience in fuzing from science and technology through production and sustainment. 16 years as the Fuze Division Chief, Army Armaments Research Development and Engineering Center (ARDEC) responsible for research, development, production, test, and evaluation of fuzes, fuze setters, and munitions power sources. Served 17 years as the Army Lead on the DoD Fuze IPT addressing technology and industrial base issues. Served 9 years as the Army member on the Joint Fuze Technology Panel overseeing a joint S&T program sponsored by OSD, addressing department technology gaps in fuzing and fuzing systems. Led development program on the M734A1 Multi-option Fuze for Mortars, led production program for PATRIOT M143 S&A Device. M.S. Mechanical Engineering, DAWIA Level III SPRDE Certified, Secret Clearance.

Defense Electronic Systems

REGISTRATION & OPENING RECEPTION SPONSOR

L3 Defense Electronic Systems (L3 DES), a division of L3 Technologies, Inc., provides precision electronic components, subsystems, and systems for the Department of Defense and international allies. L3 DES specializes in the design and manufacture of build to print and modernized fuze solutions, ignition safety devices, proximity sensors, inertial measurement and GPS navigation systems, assured position, navigation, and timing (A-PNT) capabilities, aerospace status indicators, and intelligence management systems. As a trusted partner, you can count on L3 DES to deliver quality products and develop superior solutions that enhance capabilities and provide overmatch superiority to the warfighter.

Headquartered near Cincinnati, Ohio, L3 DES' primary manufacturing facility was specifically designed and constructed for the manufacture of fuzing and ordnance systems and precision electronic components. With additional locations in Anaheim, CA, Budd Lake, NJ, and San Diego, CA, L3 DES has strategically located its resources, including program management, engineering, and quality assurance, at each site to ensure complete adherence to programmatic and technical requirements, enabling process efficiencies.

Dedicated to continuous improvement, L3 DES operates a quality management system certified to AS9100D and ISO 9001:2015 standards. With highly flexible manufacturing operations, L3 DES can accommodate a variety of products, with run rates that can exceed 40,000 units per month down to individual production units for development efforts. L3 DES also has on-site inspection and test capabilities to perform all required environmental test procedures.

At L3 DES, customer focus is a key element of who we are and how we operate. Our customers are the foundation of our success and we are committed to establishing long-term relationships and ensuring collaboration throughout the product lifecycle.

L3 DES is committed to supporting the warfighter. We will continue to innovate and develop unique solutions by leveraging our valued workforce. To learn more, please visit www.L3T.com or call 513-943-2000.

GRAND RECEPTION SPONSOR

At Northrop Grumman, we are focused on providing our warfighters with high-quality products that provide overmatch in a number of land, sea, and air engagement scenarios. Key to the effectiveness of many U.S. and ally weapon systems are our advanced bomb fuzes and proximity sensors. Our fuze portfolio includes electronic and electro-mechanical bomb fuzes that are capable of penetrating deeply buried targets, engaging high speed maneuverable surface threats and delaying detonation for mission success, while our sensors detect the height of a weapon above a target and operate in an electronic countermeasure environment. For more information, speak with one of us during the conference or visit us at northropgrumman.com.

Fuzing & Precision Products

WEDNESDAY LUNCH & WRISTBAND SPONSOR

Kaman Precision Products is the integration of two respected ordnance manufacturers in the United States: Raymond Engineering of Middletown, Connecticut, and Dayron, Inc. of Orlando, Florida. Two great defense manufacturers, one specializing in missile fuzing and one specializing in bomb fuzing, came together to create a company that serves many of the U.S. and international militaries' missile and bomb systems. Kaman Precision Products provides design, development, test and manufacture of fuzing, safe and arm, and flight termination products and systems. In addition, we design and build inductive (eddy current) sensors for operation in severe conditions, and advanced data storage and retrieval systems for military applications. Our products are found on many new and legacy missile systems such as Maverick, Harpoon, Tomahawk, ATACMS, STANDARD, Hawk and AMRAAM. Our fuzing products segment is also involved with high-g, 3 axis data recorders and flight termination Safe & Arm systems.

TUESDAY LUNCH SPONSOR

Excelitas Technologies is a leader in the design, test, and manufacturing of Electronic Safe, Arm and Fire (ESAF); Electronic Safe and Arm Devices (ESAD); and Firing Modules (FM) for safe fuzing requirements of both legacy and next-generation missiles and munitions. Our dedicated staff of research and design experts use the latest advances in technology to design smaller, lighter, and more cost effective ESAFs and FMs to meet evolving requirements of newer more sophisticated weapon systems. Capabilities include a line of components and subsystems that have been qualified for hard target penetration environments as well as for the next generation of smaller class munitions.

We also produce a large array of custom energetic devices to meet specific customer requirements for many Department of Defense and National Nuclear Safety Administration systems. Excelitas ensures the reliability and consistent performance of each energetic device through control of in-house recrystallization, processing, and pressing of our own explosive powders.

DISPLAY HOURS

MONDAY, MAY 13
5:00 – 6:00 pm

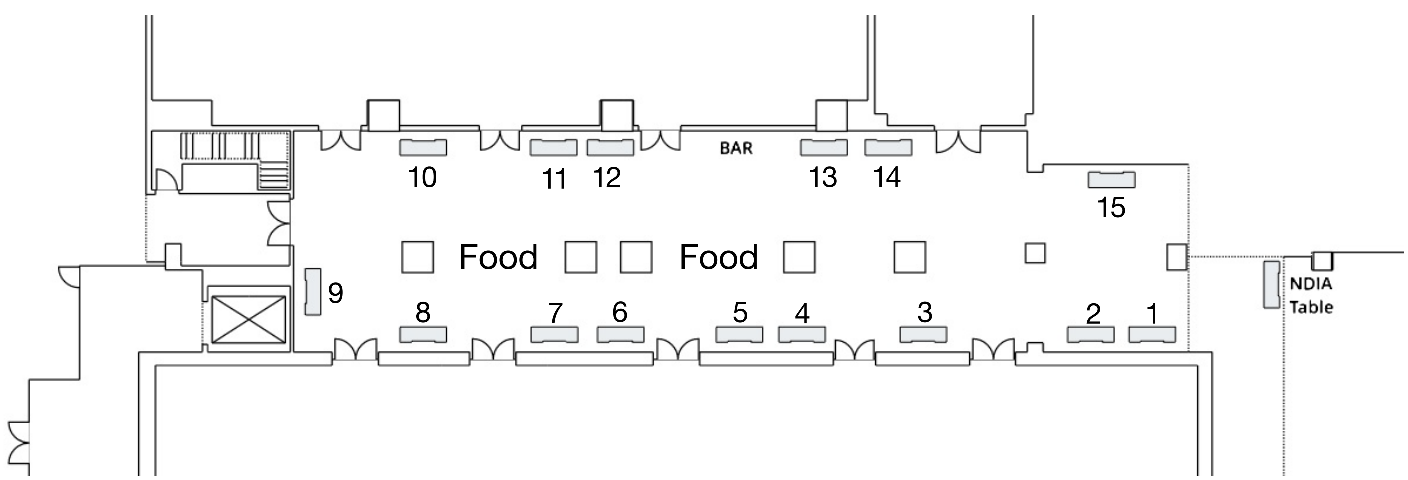
TUESDAY, MAY 14
7:00 am – 5:00 pm

WEDNESDAY, MAY 15
7:00 am – 3:20 pm

TABLE TOP DISPLAYS

Diehl & Eagle-Picher GmbH	#11
EnerSys	#8
Excelitas	#12
EXPAL Systems, S.A.	#14
Gowanda Components Group	#3
HT MicroAnalytical, Inc.	#1
Knowles-Novacap	#6
Meggitt Endevco	#4
NASCENTechnology Manufacturing, Inc.	#15
PCB Piezotronics, Inc.	#13
Presidio Components, Inc.	#9
Silicon Power Corporation	#2
Space Electronics, LLC	#10
Teledyne e2v (UK), Ltd	#5
Thiot Ingenierie	#7

DISPLAY MAP



DIEHL & EAGLE-PICHER GMBH #11

Diehl & Eagle-Picher GmbH (D&EP), is one of Europe's leading manufacturers of individualized pow-er supplies for the military and civil market.

Diehl & Eagle-Picher a German-American joint venture, develop and produce activatable thermal bat-teries for defence applications and customized battery packs for both the defence and civil market. In addition, more than 15 years ago D&EP furthermore began to design and manufacture lithium reserve batteries for applications in proximity, time and multifunction fuzes used for mortar, artillery and naval gun ammunition.

In 2013 Diehl & Eagle-Picher started a new development in the field of defence in order to minimize the size of lithium thionylchloride (Li/SOCl2) reserve batteries in response to the trend towards more efficient and less energy requiring fuzes in the medium caliber sector. The system lithium thionylchlo-ride (Li/SOCl2) for Reserve batteries stands out due to extremely high energy density. Therefore, es-pecially these minimized batteries are perfectly suitable to deliver energy for fuzes used in medi-um/large caliber ammunition for rocket and grenade weapons.

Diehl & Eagle-Picher are a most flexible partner corresponding to various customer demands due to different modular design possibilities of our batteries.

ENERSYS #8

EnerSys, the global leader in stored energy solutions for industrial applications, has an Advanced Systems division solely focused on powering submarines to satellites. Our mission is to design and manufacture custom, state-of-the-art batteries for military, space and aviation applications. By leveraging 50 years of experience in powering Fuzing applications, we remain at the forefront of powering advanced weapons across the Department of Defense. Our proprietary Cobalt Disulfide chemistry also raises the bar for what is possible with Thermal batteries for Munition applications. EnerSys Advanced Systems' wide breadth of technologies and capabilities allows us to provide our customers with the best performing products and highest quality services at the best possible value.

EXCELITAS #12

See company description on page 15.

EXPAL SYSTEMS, S.A. #14

EXPAL Systems is a global defense and security company. We offer high-end technology products, services and solutions to meet the current and future needs of Air, Land and Sea Armed Forces.

We are a trusted ally in over 60 countries adding safety, precision and advanced systems to any mission. EXPAL manages the entire life-cycle of ammunition, from R&D and manufacturing to maintenance and integration services, up to our leading demilitarization solutions.

From its Fuzes Excellence Center, a cutting-edge facility located in Europe, the company designs, manufactures and integrates a wide portfolio of fuzes. Among its latest developments, the company produces electronic FMCW proximity fuzes: a sophisticated solution that integrates time, proximity and impact functioning modes. This safety and reliability system have been proved, even when subjected to the most severe and adverse on-board electromagnetic environments.

EXPAL's fuzes, designed following the latest NATO standards, are compatible with the most demanding ammunition systems and are currently in use in over 35 armed forces all over the world.

EXPAL supports the U.S. Armed Forces through its subsidiary company EXPAL USA. Headquartered in Dallas since 2011, EXPAL USA has state-of-the-art facilities in Texarkana and a R&D center in Camp Minden to develop demilitarization services for the U.S. Army and energetic materials for the US DoD, holding the potential to extend its capabilities to the rest of EXPAL offering.

GOWANDA COMPONENTS GROUP #3

GCG designs and manufactures reliable, robust, high-performance magnetics and filters for use in demanding applications in military, aerospace, medical and communication systems around the world. GCG has a unique combination of product breadth, custom-design capabilities, proprietary equipment, in-house environmental testing and multiple facilities, all located in the USA. With more than 150,000 sq. ft. of manufacturing/engineering space spread out over six locations, GCG is disaster-plan qualified. Nearly 10,000 sq. ft. of machining space, including in-house transfer molding capability, provides quick turnaround of prototypes. All of this combined with other in-house vertical integration, helps GCG to streamline its operations and manage process flow, thereby reducing time-to-market for customers. GCG affiliates include Gowanda Electronics, DYCO Electronics, HiSonic, Butler Winding, Communication Coil, Gowanda REM-tronics, TTE Filters, Microwave Circuits, and Instec Filters.

Magnetics Products include RF & power inductors: broadband, QPL, high-reliability for space; RoHS & Pb; chips, chokes, coils, common-mode, conicals, toroids, transformers; surface-mount, thru-hole; AS9100, ISO9001. Filters Products include RF & microwave filters: bandpass, band-rejection, highpass, lowpass; Bessel, Butterworth, Chebyshev, Elliptical-Function, Gaussian; multiplexers; bias tees; and EMI/RFI filters: feed-thru's & bolt-styles.

GCG products are utilized in numerous space projects: NASA Europa, Delta IV heavy, James Webb Space Telescope, MAVEN, LADEE, and GOES-R.

HT MICROANALYTICAL, INC. #1

HT Micro's mission is to replace conventionally manufactured switches and connectors with the smallest, most robust metal microfabricated products. For military applications such as safe and arm, target detection, and guidance systems, the Company produces the smallest and most reliable, passive, surface mount inertial switches in the world. The product line can survive 100,000+ Gs while still responding to nominal thresholds ranging from 2 to 10,000 Gs. The company's entire product line and data sheets can be found at www.htmicro.com.

KNOWLES–NOVACAP #6

Novacap, a Knowles Precision Devices Brand, features high temperature, high energy capacitors designed for reliable operation under single or multiple pulse firing applications. Energy density exceeds that of conventional Class 1 materials, providing excellent short duration pulse delivery at temperatures to 200°C. Integral bleed resistors are offered in a range of values.

Capacitors are 100% tested to application tailored, Novacap high reliability screening and evaluated at operational extremes consistent with munitions and oil field exploration/seismic detonation conditions. Other applications include power supply filtering, energy storage and coupling/decoupling. Custom size, voltages and capacitance ratings are available in single, series and series/parallel arrangements.

A division of Knowles Corporation, Knowles Precision Devices is a leading global innovator and manufacturer of high performance solutions. We focus on production of a wide variety of highly engineered Capacitors, EMI and Microwave to Millimeter Wave components for use in critical military, medical, industrial, electric vehicle, and 5G market segments. From 8,000 feet below the earth's surface to orbiting 254 miles above on the ISS, we take on the complex challenges that come with High Reliability, High Temperature, High Performance, High Energy and High Frequency solutions. Our Heritage Brands include Compex, DITF, DLI, Johanson, Novacap, Syfer and Voltronics.

MEGGITT ENDEVCO #4

Meggitt is a leading supplier of high-performance sensing and monitoring systems for physical parameter measurements in extreme environments. Meggitt's Endevco® range of piezoelectric, piezoresistive, Isotron® and variable capacitance accelerometers, piezoresistive pressure transducers, acoustic sensors, electronic instruments and calibration systems ensure critical accuracy and reliability within aerospace, automotive testing and medical applications.

NASCENTECHNOLOGY MANUFACTURING, INC. #15

INASCENTechnology Manufacturing manufactures High-Reliability, High Temp transformers and inductors for commercial and military grade markets. We operate with a class 10,000 clean room and our Quality system is compliant with ISO9000:2015, AS9100D, and PQR1060 issue U. We maintain permanent, full traceability for all of our manufactured parts to materials and testing data.

Our Low-Temperature Co-Fired Ceramic transformers and inductors are flat, thin, and a fraction of the size of wire-wound transformers. The LTCC transformer imbeds the coil windings within one solid unit making it a miniature monolith. As a result, they are far more reliable, and able to withstand extreme shock and vibration.

NASCENTechnology will also manufacture custom wire wound products with a focus on producing parts that are highly reliable in adverse conditions.

Our staff continues to research ways to process, apply, and combine magnetic materials that enhance the performance of our existing designs as well as meet the needs of future applications. For example, ceramic flyback transformers operational beyond 200-degree C are now available. Stop by and visit with us today.

PCB PIEZOTRONICS, INC. #13

PCB Piezotronics, Inc. is a designer and manufacturer of microphones, vibration, pressure, force, torque, load, and strain sensors, as well as the pioneer of ICP® technology used by design engineers and predictive maintenance professionals worldwide for test, measurement, monitoring, and control requirements in automotive, aerospace, industrial, R&D, military, educational, commercial, OEM applications, and more. With a worldwide customer support team, 24-hour SensorLineSM, and a global distribution network, PCB® is committed to Total Customer Satisfaction. Visit www.pcb.com for more information. PCB Piezotronics, Inc. is a wholly owned subsidiary of MTS Systems Corporation. Additional information on MTS can be found at www.mts.com.

PRESIDIO COMPONENTS, INC. #9

Founded in 1980, Presidio Components is a US manufacturer of high reliability ceramic capacitors. One of our product line focused on pulse energy capacitors for Exploding Foil Initiator (EFI) used in fuse systems for missiles and ordnances. As an added safety feature, our pulse energy capacitors can be ordered with bleed resistors. Lead frames are also available for board flex compliance. Energy output is designed to match customer requirements.

Overall Presidio supplies ceramic capacitors used in other high reliability industrial, military or space applications. Presidio's power products include low inductance chips SMD, high reliability SMPS stacks, and high voltage radial leads.

Presidio's RF Power and RF /Microwave product group features Ultra-Porcelain™ capacitors with ultra-low ESR and ultra-high Q, broadband DC blocking capacitors, as well as the smallest wire-bondable single layer and broadband bypass capacitors available.

Presidio is qualified to most MIL specs including the highest established reliability rating of 'S' Level for MIL-PRF-55681. All QPL testing per MIL-STD-202 is done on site in Presidio's DSCC approved test lab.

SILICON POWER CORPORATION #2

Silicon Power Corporation is a developer and solutions provider dedicated to the design, development, testing and manufacturing of high-voltage semiconductor switches, high-voltage pulsed-power switches, and high-power utility-applicable systems.

Through its SolidTRON product group, Silicon Power assembles, tests, and delivers to the defense industry proprietary semiconductor discharge switches, which are designed into the critical fuze initiation of numerous active smart weapons programs.

Silicon Power's Pulsed Power product group offers the world leading technology in solid state high-speed, high voltage, and high-energy transfer switches. Beginning with the design of the constituent semiconductors, SolidTRON, our focus is enabling system-level designs with unprecedented performance compared to other solid state thyratron, ignitron and spark gap.

SPACE ELECTRONICS, LLC #10

ISpace Electronics is the world's leading manufacturer of totally safe igniter / squib circuit testers. Our SQB Series consists of automated multi-node systems, rackmount testers and portable single channel units. These systems are ideal for safely measuring the resistance and stray voltage in a weapon's multiple electrical circuit paths.

Customers such as the US Navy, Raytheon, Boeing, L3 Technologies and Lockheed Martin rely on Space Electronics systems to safely test rocket igniters, fuses, explosive bolts, squibs, detonators and electro-component lines (relays, actuators, diodes and semiconductor devices). Our designs incorporate multiple layers of safety and internal microprocessors. These features produce highly accurate, rapid and stable readings, while drastically reducing the risk of accidental detonations.

We designed and built our first squib meters in 1977 (many of our original units remain in use and we continue to support them). Space Electronics customers benefit from our detailed version control and world class customer service.

THIOT INGENIERIE #7

THIOT INGENIERIE, shock physics specialist since 1988, is working in two main activities around its expertise in shock physics.

First in design and manufacturing test equipment for fast dynamics studies:

Gas guns | Acceleration generator | Split Hopkinson bars | Detonation chamber

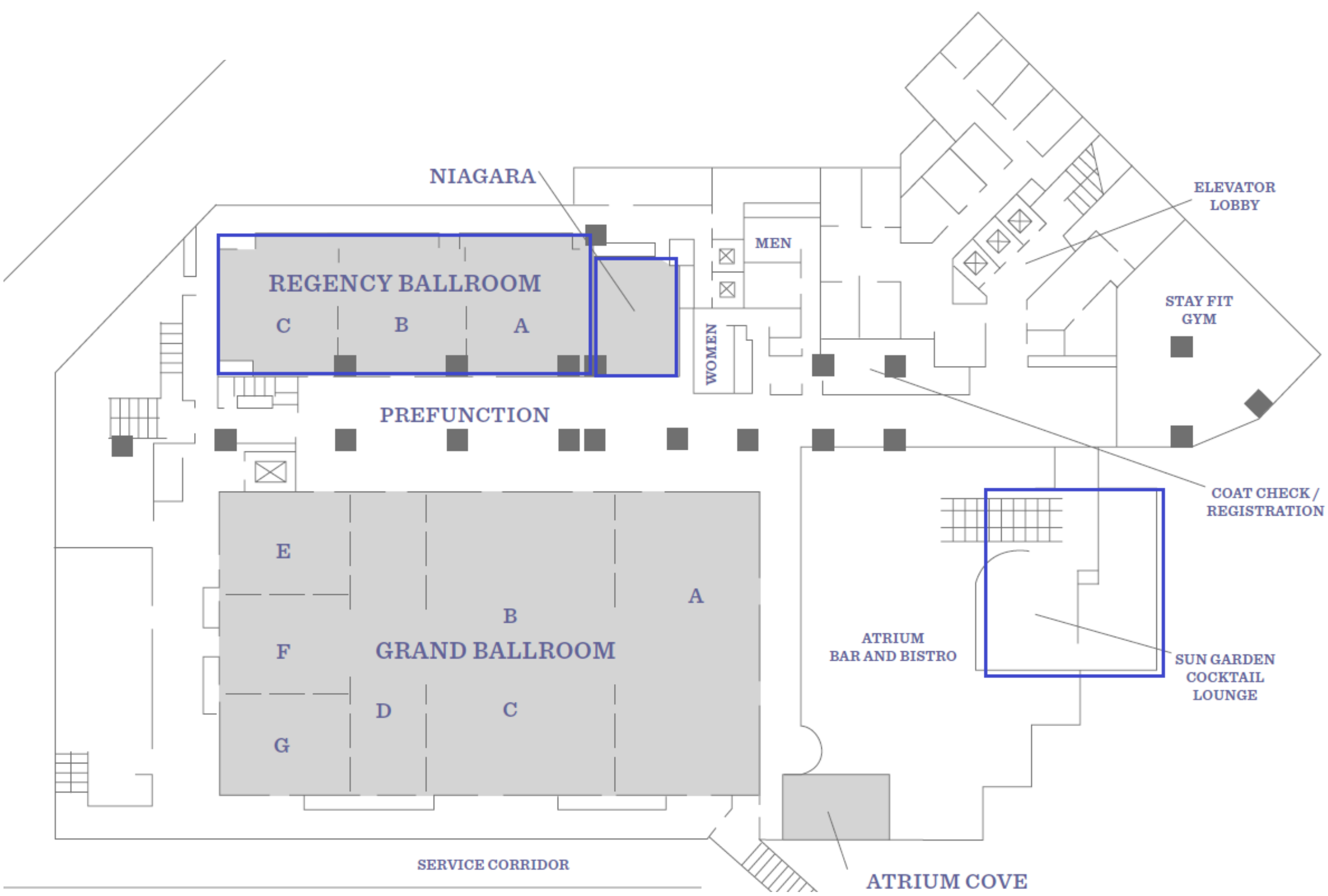
The second parts of its activity is a high level of expertise in shock physics with a terminal ballistics laboratory and a R&D department specialized in dynamic behavior of materials.

Our philosophy: To combine experimental tests results to numerical simulation to have the best knowledge of the material behavior.

Our equipment:

- 4 gas guns for impact tests: we can fire any type of projectile onto any kind of target from 50m/s up to 8500m/s (i.e. we can reproduce fuze behavior during impact).
- Numerical simulation: with our expertise in numerical simulation, we are able to simulate the behavior of your structures in all types of shock situation: ballistic impacts on armor, explosions inside a building or acceleration and/or deceleration phenomena.
- Mechanical characterization (Hopkinson bars tests, dynamic press).
- Acceleration testing (up to 100 000G): to observe and study the behavior of embedded systems under high levels of stress (MEMS, IMU, SAU).

VENUE MAP



NDIA CELEBRATES 100 YEARS!

The technology used by today's modern warfighter was unimaginable 100 years ago. In 1919, BG Benedict Crowell's vision of a collaborative team working at the intersection of science, industry, government and defense began what was to become the National Defense Industrial Association. For the past century, NDIA and its predecessor organizations have been at the heart of the mission by dedicating their time, expertise and energy to ensuring our warfighters have the best training, equipment and support.

Reflecting on NDIA's history, we embrace the opportunity to emphasize the need for legal and ethical collaboration among military, government, industry and academia to ensure the defense industrial base is prepared for future challenges and conflicts. Just as the early 20th century was characterized by massive transformation in military capabilities, emerging trends in technology and increasing geopolitical challenges demand new strategies and policies in today's national security landscape.

THANK YOU TO OUR SPONSORS

L3 Defense Electronic Systems

NORTHROP GRUMMAN

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JUNGHANS Defence

PACSCI EMC

PCB PIEZOTRONICS
MTS SYSTEMS CORPORATION

NOTES

U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND – ARMAMENTS CENTER

Fuze S&T Overview at the 62nd NDIA Fuze Conference

Charles Robinson

Fuze HQ Staff Engineer

Fuze & Precision Armaments Directorate, Fuze Division

DD MMM YYYY

Distribution Statement A: Approved for Public Release Distribution Unlimited

CCDC-ARMAMENTS CENTER FUZE S&T

Organization

- Army Futures Command
- CCDC-AC and facilities
- Modernization Priorities
- FD Products and S&T Investment Areas

Ongoing Fuze Projects

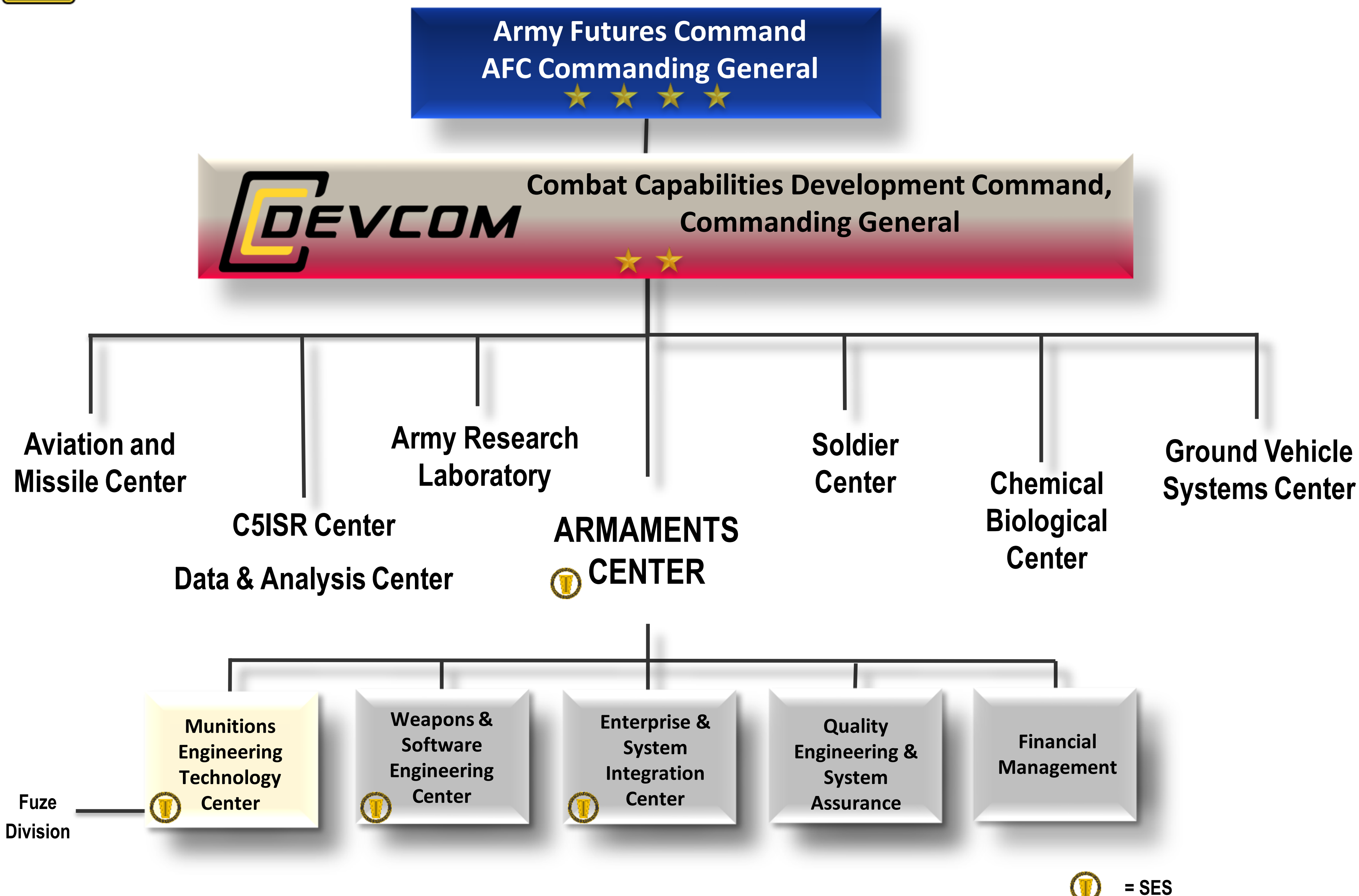
Changes to Fuze S&T Focus

- Foundational Technologies (6.2)
- S&T Focus Definition Process
- FY20-FY25 Areas of Interest

Collaboration

Individual presentations

CCDC-AC CHAIN OF COMMAND



TEAM PICATINNY

Other Tenants

PEO Soldier
PM Soldier Weapons

PEO Ground Combat Systems
PM Ground Combat Vehicle

DCMA - Springfield

Civilian Human Resources Agency

Naval Surface Warfare Center

Marine Corps G Co 2-25

Army Contracting Center – ACC- NJ

Recruiting Northern NJ HQ (Company)

7245th Installation Medical Support Unit

Combat Capabilities Development Command – Armaments Center CCDC-AC

CG/JPEO Armaments & Ammunition

- PM CCS
- PM CAS
- PM MAS
- PM TAS
- PM JS
- PM JP

Joint Munition & Lethality LCMC

Garrison Commander

Office of the Executive Director for Conventional Ammunition O/EDCA

DoD Joint Specialty Site for Guns and Ammunition

CCDC - ARMAMENTS CENTER


RESEARCH


DEVELOPMENT


PRODUCTION


FIELD SUPPORT


DEMILITARIZATION

Advanced Weapons:

- Line-of-sight (LOS), beyond line-of-sight (BLOS) and non line-of-sight (NLOS) fire
- Scalable effects; non-lethal; directed energy; autonomous weapons.

Ammunition:

- Small, medium, large caliber
- Propellants; explosives; pyrotechnics; warheads; insensitive munitions
- Fuzes
- Logistics; packaging; environmental technologies and explosive ordnance disposal

Fire Control:

Battlefield digitization; embedded system software; aero ballistics and telemetry

"Center of Mass" for Armament Systems and Munitions for Joint Services

FUZE DIVISION PRODUCTS/PORTFOLIO

WORLD-CLASS FACILITIES

DEVCOM ARMAMENTS CENTER

Armament Software Engineering Center

Ballistic Gun Range Complex

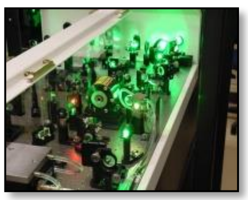
Energetics Synthesis, Formulation and Scale-up Complex

High Performance Propellants Complex

Davidson Warhead Facility

Automated Test Sets Facility

Fuze Development Center



Directed Energy Facility

Electromagnetic Effects Complex

Remote Armaments Facility

Soft Catch Gun Facility

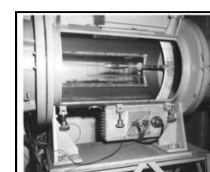
Our Organic Facilities Enable Integrated Armament System Solutions

Demilitarization Facility

DoD Joint Packaging, Handling, Storage, and Transportation Complex

Drop Tower Facility

Non-Destructive Evaluation Facility



Wind Tunnel Facility

Precision Armaments Complex

ARMY MODERNIZATION PRIORITIES

- **Cross Functional Teams (CFTs)**
  - **Long Range Precision Fires**
  - **Next Generation Combat Vehicle**
  - **Future Vertical Lift Platforms**
  - **Mobile & Expeditionary Army Network**
  - **Air and Missile Defense**
  - **Soldier Lethality**
- **CFTs: vehicle for sustainable reform of acquisition process**

FUZE S&T INVESTMENT AREAS

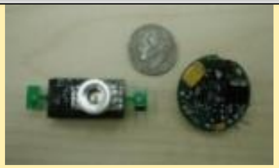
Advanced Fuze Setting
- PIAFS, ePIAFS, iPIK
- Medium Caliber setters

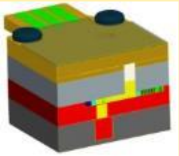

PIAFS


EPIAFS

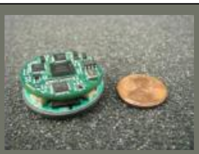
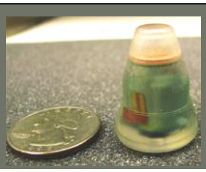

iPIK

Advanced Warhead Initiation Schemes
- ESAD, miniature and embedded firesets, low-cost multi-point
- Micro-Scale Firetrain (MSF)

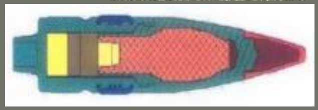


Launch and Target Sensing
- Next-Gen Prox and small, low-cost, robust
- G-Switch, Target Media Sensing



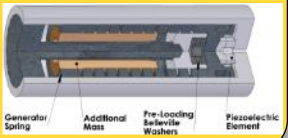



Fuze Decision Logic

Novel Power & Energy
- Thermals, liquid reserve, harvesters

Thermals


Liquid Reserves



Advanced Safe and Arming

MEMS S&A



Rotor S&A

ONGOING FUZE PROJECTS

Gold, 17-G-
Green, 18-G-
Blue, 19-G-

Emerging & MaturingTechnologies

6.2 OSD Joint Fuze Technology Program

Muzzle Velocity Correction for Medium Caliber, Neeb
MEMS Stab Detonator, Romaniello
Flyer-Enabled MEMS S&A, Ziegler
Net Munition, Zienowicz
Near Burst Prox Fuze & Range Doppler Tracking Algorithm, BB
Miniature Setback Generator, Romaniello
Low Cost Tracking Proximity Sensor, Barton
Fuze Component Functionality During High-Shock Events, Neeb
Characterization of Engineered Wood Targets, Ginetto
Fracture & Damage Mechanisms of LIGA MEMS, Smyth

6.3 OSD Joint Fuze Technology Program

Target Scene Generator, Cook
Determination Optimal Potting Hi-G Electronics & Fuzes, Haynes
MEMS S&A Command Latch, Robinson
Replacing Lead Azide with DBX-1, Sweterlitsch
Low-Cost, High-Voltage Power Generation for ESAD, Pirozzi & Khuc
COTS Accelerometer As Impact Sensor, Scaduto
MEMS Escapement S&A, Romaniello
Gun Launch Harvesting for Spin & Nonspin Rounds, Ziegler

AFC-CCDC-Armaments Center S&T Projects & Demonstrations

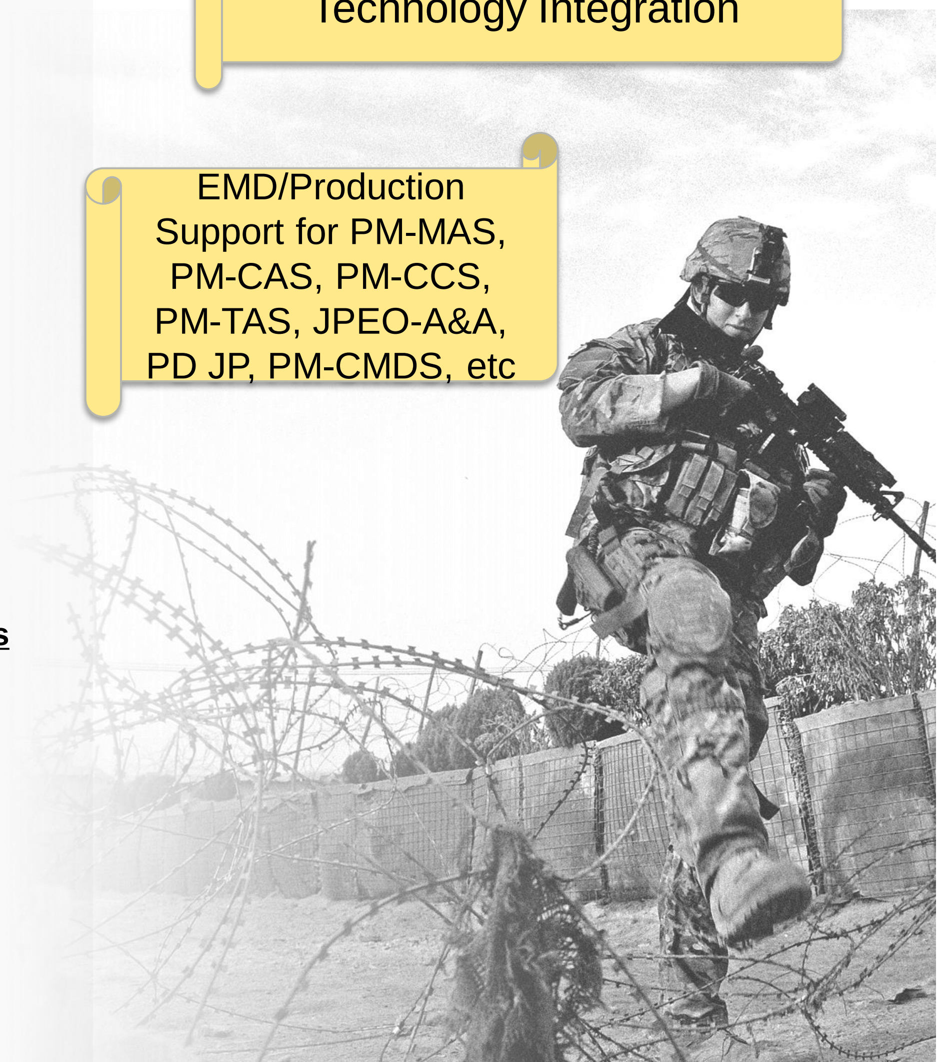
Fuze & Power Tech Enablers: FEAR, NGS&C, NGLCS and PAM
Aviation Armaments System Technologies (30mm ask TE)
Cluster Munitions Replacement Technology
XM1166 HEAB
Fuze & Power Technology Enablers for Munitions

6.7 Fuze Technology Integration Efforts

M734A1 Electronics Upgrade
Replace Obsolete Prox Electronics Components
M550 Spinlock Redesign
ESAD Enhancements for Precision Munitions
Hand Grenade Fuze Improvements
Power Source Improvements and M734A1 µC Replacement

On-going 6.7 RDTE Fuze Technology Integration

EMD/Production Support for PM-MAS, PM-CAS, PM-CCS, PM-TAS, JPEO-A&A, PD JP, PM-CMDS, etc



FORWARD-LOOKING S&T AREAS OF INTEREST

- Many Point ESADs for Multi-Role Munitions
- Hyper Velocity Fuzing and Power
- Embedded Electronic Fuzing
- MEMS S&A Dynamic End-to-End Model
- Reserve batteries
- Super Capacitor Material Research
- Secure Wireless Data Transmission for Fuze Setting
- Networked Fuzing Architectures
- Low Cost Tracking Proximity Sensors

ADJUSTED S&T FOCUS

- **FY20-25 S&T “Foundational Technology” 6.2 (applied research) up to TRL5**
  - Technologies that support multiple CFT areas vs. one specific program
  - Address technical high-risk areas unlikely to be worked by industry IR&D
  - Provide a stream of foundational fuze technologies:
    - For munition developers, advanced system demonstrations, and industrial base
    - Avoid investing in proprietary technologies
  - Plausible transition into future 6.3 weapon/munition technology demonstration efforts
- **How Foundational Investment Areas Emerge**
  - CFTs and 6.3 system demonstrations
    - Alignment, balance risk, cost and technology disruption
  - Government/Industry subject matter engagements, both formal and informal

EXEMPLIFYING COLLABORATION

- **Industry to CCDC-AC engagements**
  - Formal IR&D Reviews with CCDC-AC
  - Informal IR&D Reviews with Fuze Division
  - Cooperative Research and Development Agreements (CRADAs)
  - DoD Fuze IPT
- **DOTC**
  - Industry-suggested topics
  - Annual plan feedback
  - Enhanced-whitepaper feedback
  - General Membership Meeting one-on-ones
- **Joint Fuze Technology Program**
- **OGAs**
- **DTIC Reporting**

BRIEFINGS TO FOLLOW:

Presenter/Author	Titles	Session	Time
Jeffrey Fornoff	Unmanned Systems Safety Precepts	OPEN	Tues 3:40pm
Jeffrey Smyth	Exploring High-Strain-Rate Deformation of *Metal MEMS* Using Customized Taylor Anvil Impact Test	OPEN	Tues 4:20pm
Stephen Redington	Prototyping Fuze Electronics for High Reliability Manufacturing	OPEN	Wed 9:00am
Kevin O'Connor & Kevin Aghaei	Drop Testing of LIGA MEMS Parallel Beam, Bi-Stable Latching Mechanisms	OPEN	Wed 11:00am
Laura Ostar-Exel	Development and Testing of Setback Locks for High Reliability in DPICM-XL Grenades	OPEN	Wed 3:20pm
Andrew Warne	Development of Electronics for DPICM-XL Cluster Munitions Replacement Technology	OPEN	Wed 4:00pm

BRIEFINGS TO FOLLOW:

Presenter/Author	Title	Session	Time
Lynne Rider	MEMSAD – Maturing the Technology	CLOSED	Tues 2:20pm
Charles Romaniello	Neyer Testing Results for MEMS S&A Bridgewires	CLOSED	Wed 8:40am
Jason Sweterlitsch	M550 Safe & Arm Redesign	CLOSED	Wed 9:00am
Alex Neeb	Fuze Enhanced Airburst Response (FEAR) for Medium Caliber Munition	CLOSED	Wed 10:20am
Dexter Cook	Target Scene Generator	CLOSED	Wedn 11:00am
Evan Young	CCDC-Armaments Center Fuze S&T	CLOSED	Wed 1:20pm

FUZE S&T NEEDS

How are We going to do it?

- **Foundational Technologies supporting CFT priorities**
- **Partnering and Collaboration**

62nd Fuze Conference

"Fuzing Innovations for Tomorrow's Weapons"

Thank You!!

Naval Surface Warfare Center Dahlgren Division

Navy S&T Strategy

Presented by

Jason Koonts

jason.koonts@navy.mil, 540-284-0179

62nd NDIA Fuze Conference

14th – 15th May, 2019

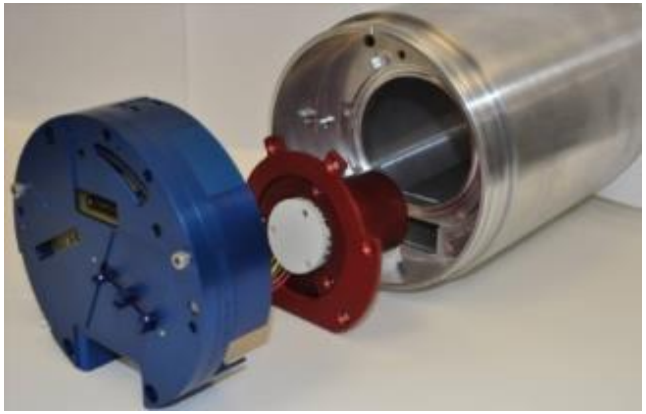
The Leader in Warfare Systems Development and Integration

Outline

- Navy Organizations
  - NSWC IHEODTD
  - NSWC DD
  - NAWCWD CL
- Navy Safety Overview
  - FISTRP
  - FESWG
- Navy Fuze R&D Highlights
- Conference Papers

Strategic Locations

NSWC IHEODTD Fuzing Overview

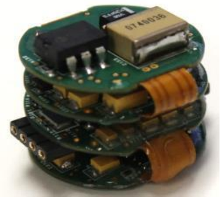


- Fuze safety architecture
- Distributed fuzing
- Firesets
- Underwater fuzes
  - Torpedoes (e.g., Anti-Torpedo Torpedo)
  - Mine/mine neutralization
- MEMS and energetics integration (explosively certified cleanroom)
- Energy harvesting
- Powerless environmental sensors
- Rapid prototyping/circuit board layout

NSWC IHEODTD Core Capabilities

Electrical Design and Test

- Electronic Safe Arm Devices (ESADs)
- Sensing technologies, imbedded systems, RF design

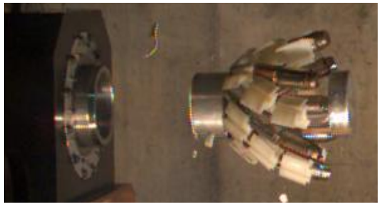


Initiation Systems Design and Test

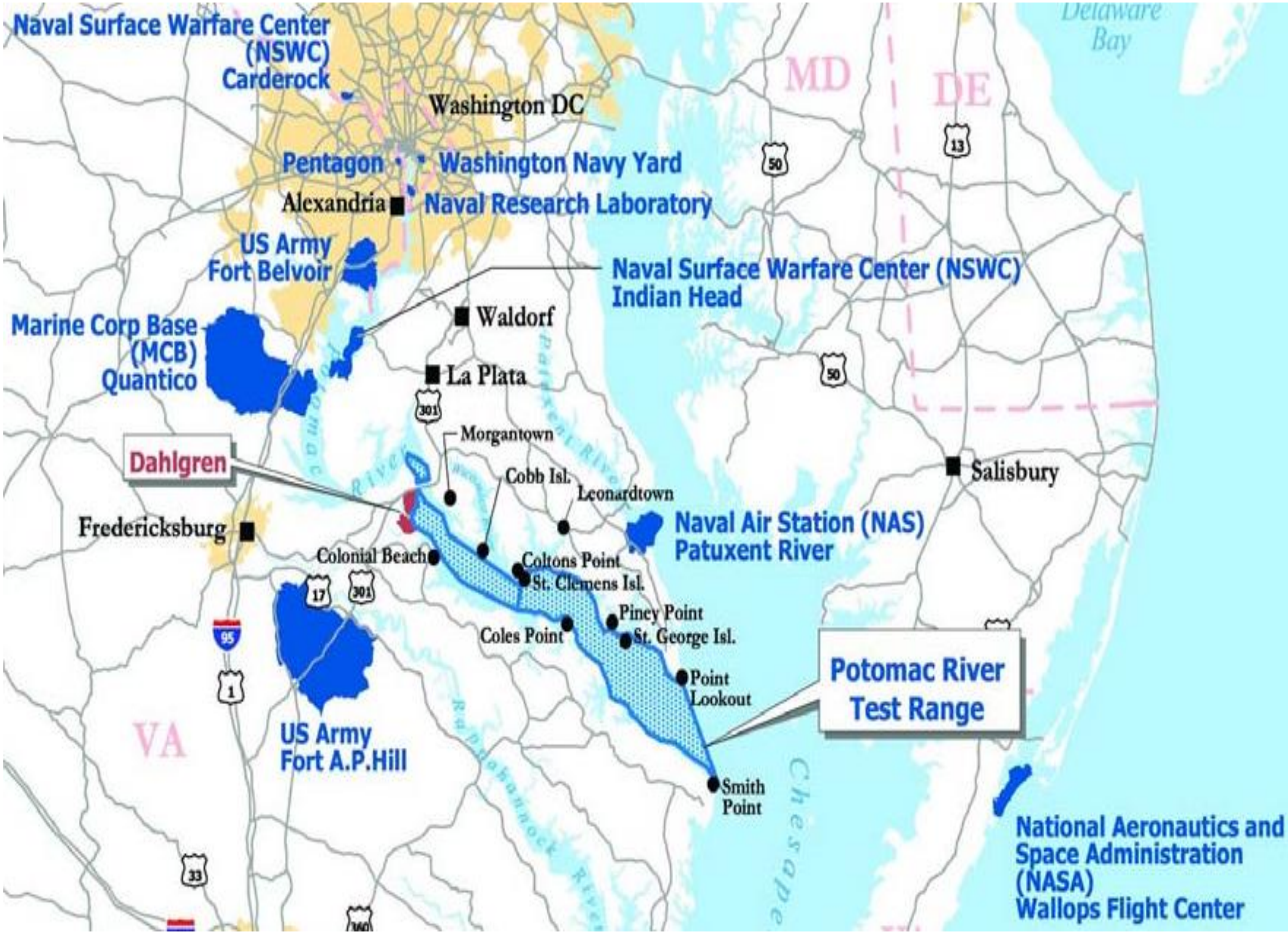
- Micro-energetics
- Characterization (e.g., Photonic Doppler Velocimetry)

Mech. Design and Test

- Fuze packaging
- Full scale launch and impact testing
- Microelectromechanical Systems (MEMS)
- High G shock testing and survivability



NSWC Dahlgren



Located on the Potomac River, 60 miles south of DC

Core Fuzing Capabilities

DEVELOPMENT

- Gun-launched, conventional ammo fuzing
- S&A design
- Preparing specs and requirements
- Benchtop electronics testing
- CAD modeling and finite element analysis
- Rapid prototyping

QUALIFICATION

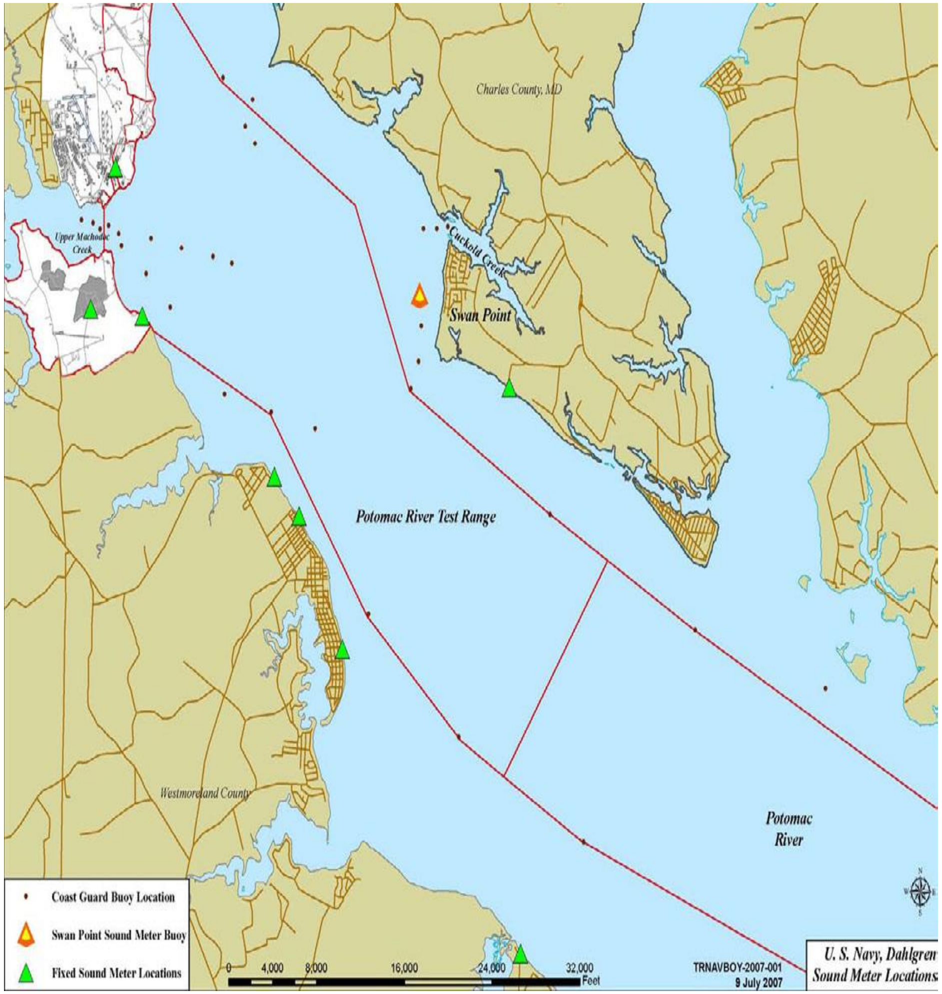
- Closed and open loop HWIL testing
- Execute and approve qualification testing
- Energetics and ballistic testing
- Extensive safety support with FISTRP representation

FLEET SUPPORT

- Direct communication with fleet
- Support various at-sea test events
- Respond to Conventional Ordnance Deficiency Reports (CODRs)
- Provide SME support/training

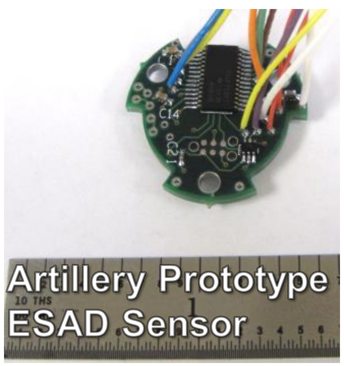
Potomac River Test Range

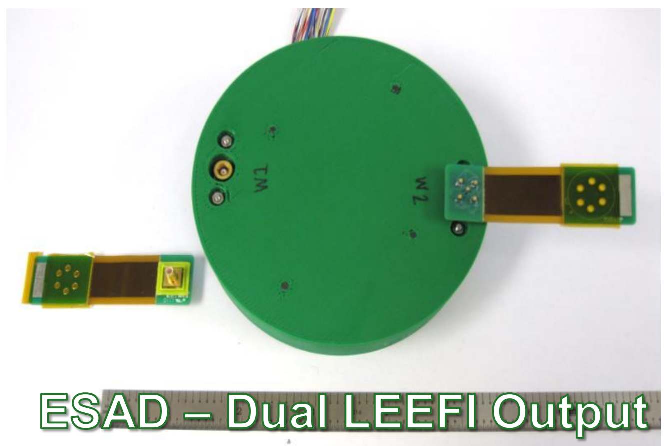
- 169 square miles of controlled water
  - Ballistic range of up to 20 nautical miles
  - Airspace clearance to 60,000 feet
- Fully instrumented network of range stations along VA shore of the Potomac River
- Over 2,300 acres of explosive ranges provide full spectrum of capabilities for live fire testing of energetics and directed energy systems
- Test range supports legacy, emergent, and "Navy after Next" programs
- Fuze test facility capable of:
  - S&A spin testing
  - Battery activation testing
  - Detonator time and explosive output testing
  - Fuze electronics testing
  - RF target simulation
  - Environmental testing



NAWCWD Engineering Overview

- Design & Develop New Fuzing Concepts
  - Rapid Prototyping (3D print or machined)
  - FPGA development and logic analysis (up to 208 channel)
  - ESADs, ISDs, FTSAs, Test Range Fire-sets





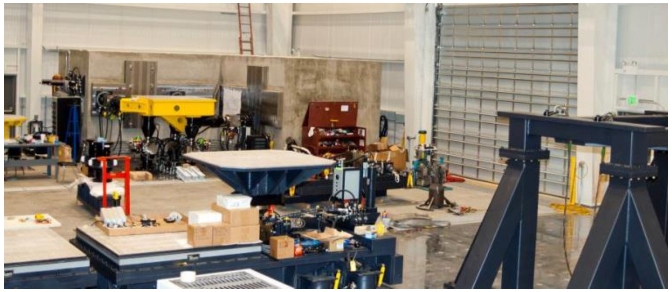
In-Service Fuze Support

- Over 50 years of combined experience
- Program support from Production through Sustainment and Ordnance Assessment
- Respond to Conventional Ordnance Deficiency Reports (CODR) from the fleet

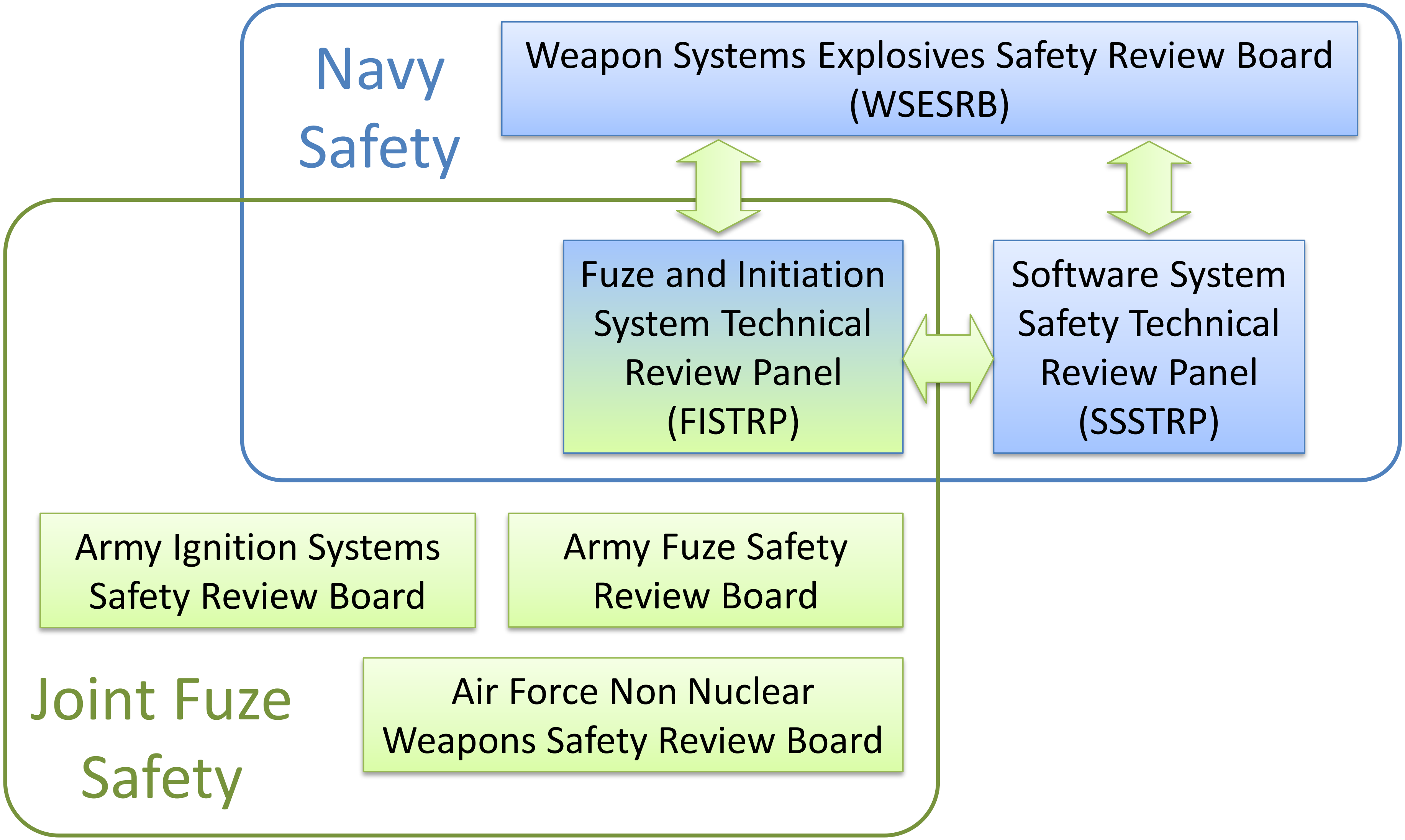


Fuze Testing Capabilities

- Environmental/Functional test sites to support Qualification, LAT, Ordnance Assessment(OA), Recertification, and experimental testing.
- Capability on-site to test AUR configurations with both multi-shaker underwing and 6DOF capabilities
- Full suite of Insensitive Munitions (IM) test facilities.
- Sled test capability



Navy and Joint Services Safety



Navy Ammunition Safety

- WSESRB formed after 1968 fire aboard USS Forrestal (CV-59)
  - Investigation recommended independent review process be established
- NAVSEAINST 8020.6E
  - "…the WSESRB is the Navy's independent oversight for safety compliance of all DON military munitions…"
  - "The FISTRP reviews specific safety aspects requiring expertise in the area of design, analyses, and testing of fuzes, initiators, safe/arm devices and ignition systems contained in weapon systems."

FISTRP Process

- Formal Reviews
  - FISTRP will draft meeting notes and record action items
  - FISTRP chair briefs WSESRB, who formally release FISTRP findings to Program
  - SSSTRP has similar process for software reviews
- Technical Assists
  - Informal meetings
  - Treated as SME opinion from available FISTRP members
  - Program can record meeting minutes, which FISTRP will review

JOTPs

MIL-STD-1316 STANAG 4187
MIL-STD-1901 STANAG 4368
MIL-STD-1911 STANAG 4497

FISTRP Membership

- Panel Chair:
  - Gabriel Soto - NAWCWD CL
- Panel Members:
  - Ralph Balestrieri - IHEODTD
  - Tinya Coles-Cieply - NOSSA
  - Michael Demmick - NOSSA
  - Michael Haddon - NAWCWD CL
  - Bradley Hanna - NSWC DD
  - John Hughes - NAWCWD CL
  - John Kandell - NAWCWD CL
  - Jason Koonts - NSWC DD
  - Daniel Lanterman- IHEODTD
  - Melissa Milani - IHEODTD
  - Adedayo Oyelowo - IHEODTD
  - Ciarra Villa - NAWCWD CL

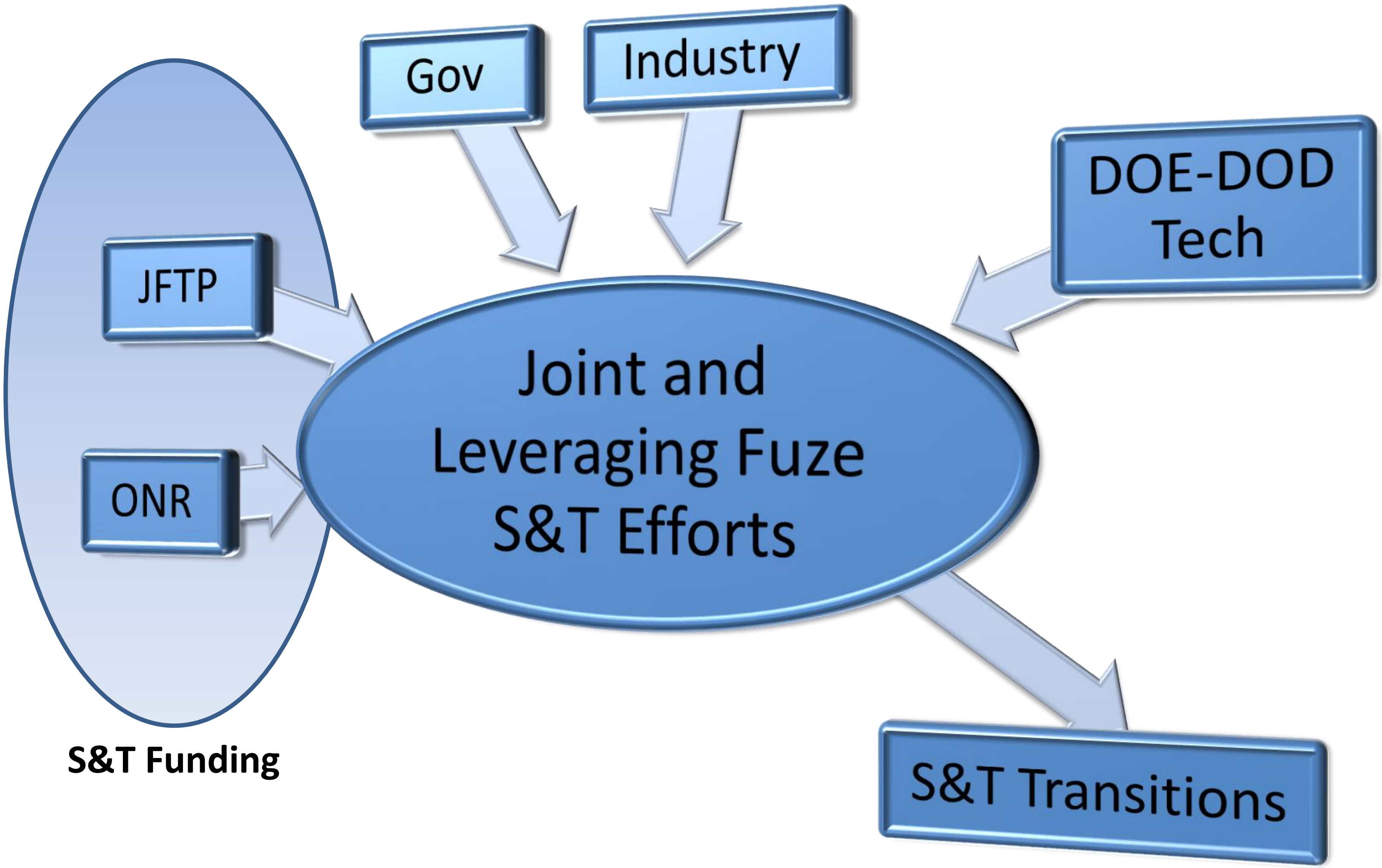
FESWG

- Fuze Engineering Standardization Working Group
  - Chartered as a Joint Standardization Board (JSB) by the Defense Standardization Program (DSP)
    - Approaching the 100^{th} meeting, originated in the 1970's
  - Objective is to achieve common, mutually satisfactory solutions to shared requirements and problems
- Chairperson
  - Homesh Lalbahadur, US Army, Picatinny Arsenal, NJ

Current FESWG Efforts

- Guidelines for evaluation of electronic safety and arming systems
- MIL-STD-1911B for hand-emplaced munitions
- MIL-STD-1901B for ignition safety devices
- Design requirements for remotely controlled safety, arming, and functioning (SAF) systems
- Safety design criteria for command and control of directed energy weapons
- Interface with NATO groups for international fuzing safety requirements

Fuzing Technology



Navy Fuze S&T Efforts

- ONR: High Reliability Dual-Purpose Improved Conventional Munition (DPICM) Replacement
- JFTP (Joint Fuze Technology Program)
  - Advance proximity sensing
  - Hard Target Survivability – Modeling & Simulation, Testing, Encapsulation, Materials
  - MEMS and micro-explosive train reliability

Summary of Navy Conference Briefs

- Session 4A (Open)
  - DoD MEMS Fuze Explosive Train Evaluation and Enhancement (8:00am-8:20am)
    - David Muzzey, NSWC IHEODTD
- Session 4B (Closed)
  - Electrical Transmission Line Replacement for Det-Cords in Flight Termination Systems (8:20am-8:40am)
    - Dustin Atwood, NAWCWD CL)
  - EFI Fire Pulse Delay Circuit (10:40am-11:00am)
    - Michael Haddon, NAWCWD CL)

Summary of Navy Conference Briefs

- Session 5A (Open)
  - Survivability and Reliability of Silicon MEMS Components (2:20pm-2:40pm)
    - Caitlyn May, NSWC IHEODTD
- Session 5B (Closed)
  - Small-Scale Testing of Electronic Components in Shock Loading (2:00pm-2:20pm)
    - Vasant Joshi, NSWC IHEODTD

U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND – AVIATION & MISSILE CENTER

Guidelines for Implementing a Low Voltage Command Arm Distributed Fuzing System

Mark Etheridge

NDIA Fuze Conference

Buffalo, NY

14-15 May 2019

MISSION

Deliver collaborative and innovative aviation and missile capabilities for responsive and cost-effective research, development and life cycle engineering solutions.

BY THE NUMBERS

DEVCOM AVIATION & MISSILE CENTER

~9,553 FY18 Strength

2,943 Civilian

23 Military

6,587 Contractor

FY18 Funding

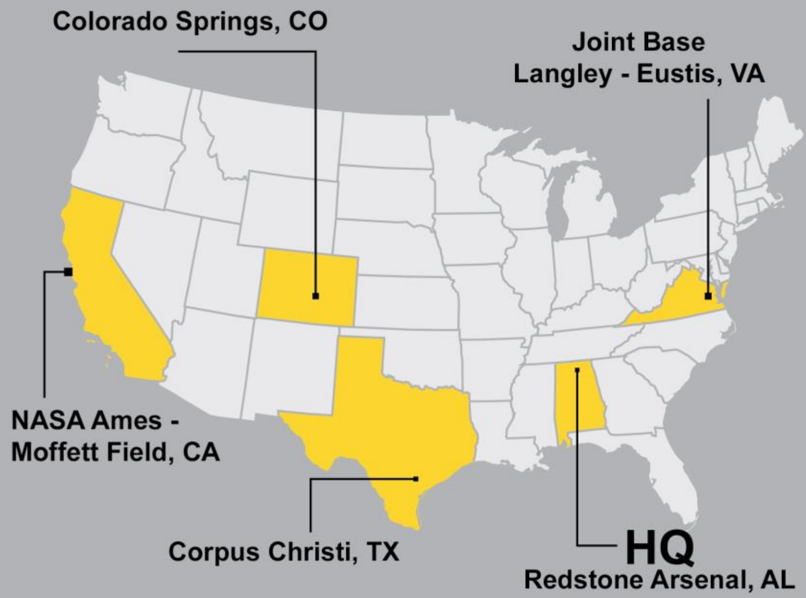
$3.4B

7% Aviation S&T

8% Missile S&T

58% Army

27% Other



Core Competencies

- Life Cycle Engineering
- Research, Technology Development and Demonstration
- Design and Modification
- Software Engineering
- Systems Integration
- Test and Evaluation
- Qualification
- Aerodynamics/ Aeromechanics
- Structures
- Propulsion
- Guidance/Navigation
- Autonomy and Teaming
- Radio Frequency (RF) Technology
- Fire Control Radar Technology
- Image Processing
- Models and Simulation
- Weapons Assurance

PRIORITIES

#1: Readiness

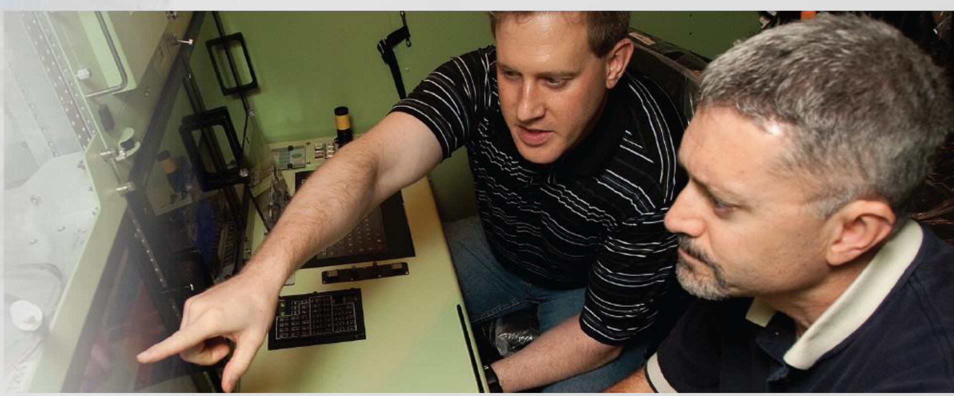
Provide aviation and missile systems solutions to ensure victory on the battlefield today.

#2: Future Force

Develop and mature Science and Technology to provide technical capability to our Army’s (and nation’s) aviation and missile systems.

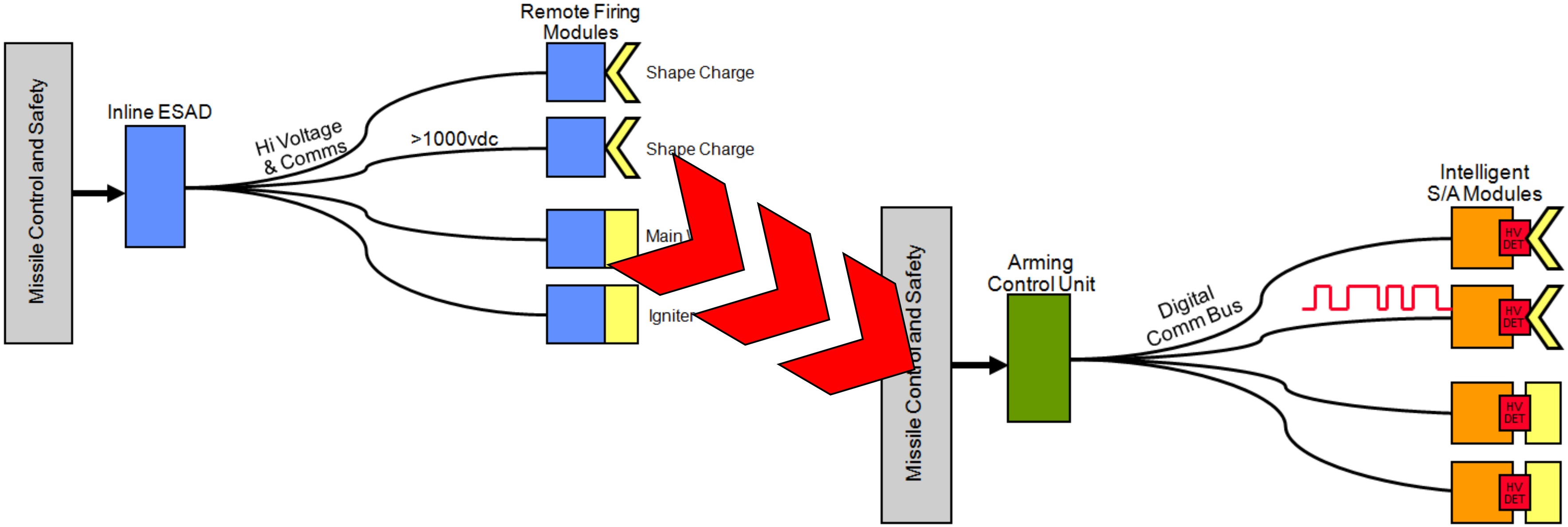
#3: Soldiers and People

Develop the engineering talent to support both Science and Technology and the aviation and missile materiel enterprise



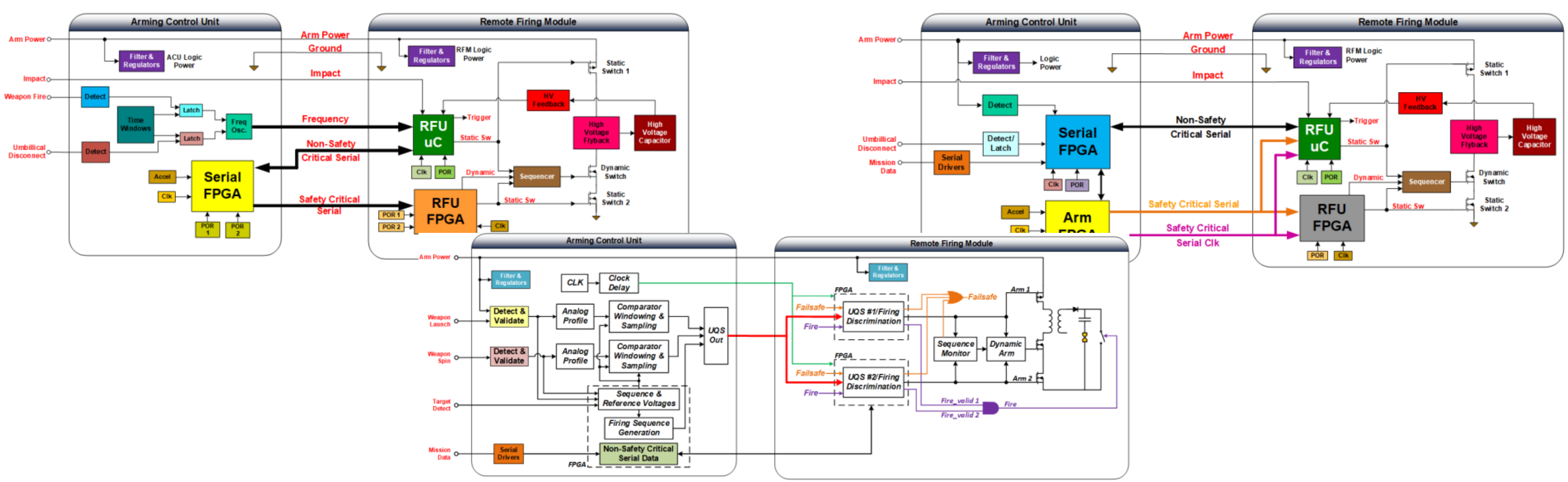
ACKNOWLEDGEMENTS

- **This project is sponsored by the Joint Fuze Technology Panel (JFTP)**
  - FATG II (Tailorable Effects)
- **Alan Durkey, Naval Air Warfare Center**
- **Adedayo Oyelowo, Naval Surface Warfare Center**



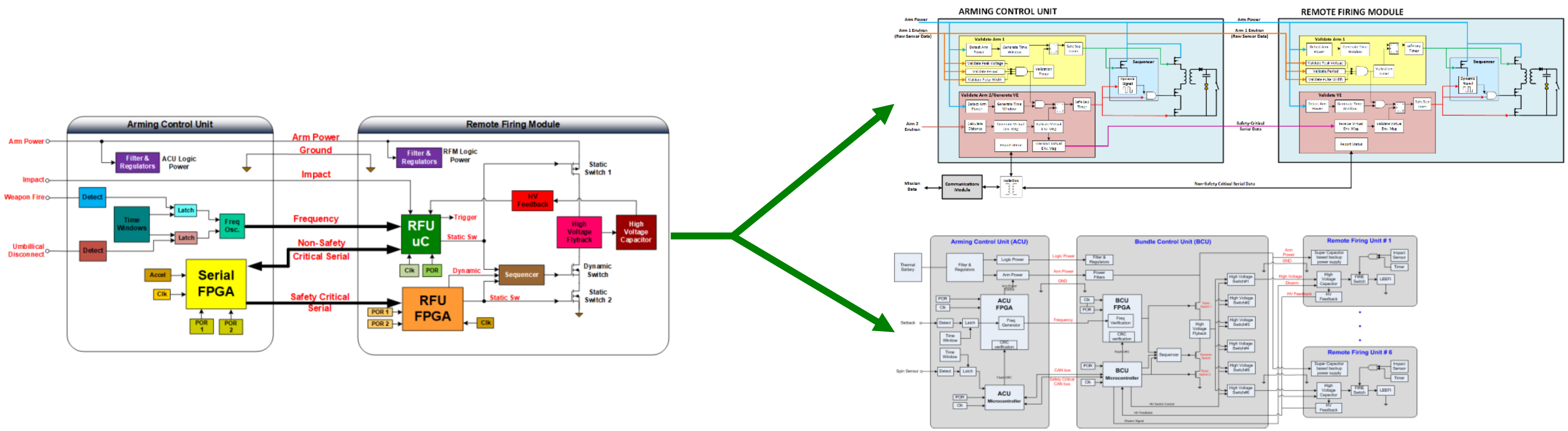
PROJECT HISTORY

- **This project began in 2010 with a 6.2 effort to develop some generic architectures so as to define some minimal hardware & signal guidelines.**
  - Participants: Army CCDC-AvMC, NAWC, Sandia
  - Architectures: Multiple-Try, Frequency Shift, eUQS
  - Successful in gaining acceptance.
    - ➢ FESWG ‘approval’ in February, 2014
    - ➢ FESWG ad-hoc stood up; JOTP document was started.



PROJECT HISTORY

- **A 6.3 program then began in 2015 to pursue form, fit, and function designs with the goal of further defining the 'solution space'**
  - Participants: Army CCDC-AvMC, NAWC, NSWC-IH.
  - Frequency Shift architecture was chosen for implementation
  - Program ending in FY19.
  - Goals met!!
    - ➢ Guidelines were refined and new architectures added.



JOTP-054
XXXXXX 2019

DEPARTMENT OF DEFENSE

JOINT ORDNANCE TEST PROCEDURE (JOTP)-054

GUIDELINES FOR THE DESIGN OF LOW VOLTAGE COMMAND-ARM (LVCA) DISTRIBUTED FUZING SYSTEMS

DoD Fuze Engineering Standardization Working Group (FESWG)

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

PLEASE NOTE!!

1. **Final review of the document has been completed and the guidelines are being published!!**

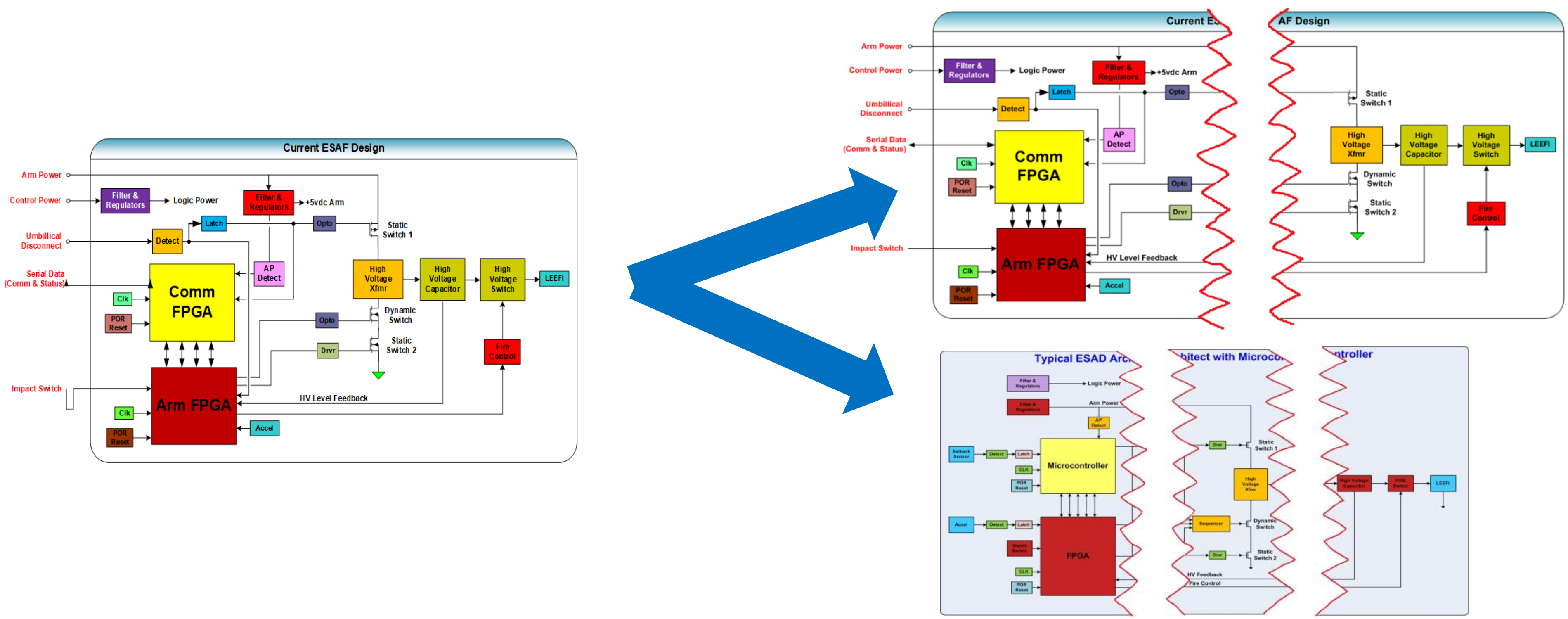
2. **The following slides are *<u>guidelines</u>*…not requirements.**
   Consult with the appropriate Service Safety Authority for acceptability if this guidance cannot be adhered too.

3. **Some of the guidelines are not presented.**

DEFINITIONS

Low Voltage Distributed Fuzing/Ignition Architecture

- **A configuration and/or architecture in which elements that influence validation of arming environments are not collocated with the elements that enable safety features..**



DEFINITIONS

- ***Environment:*** **A specific physical condition to which the fuze and/or ignition system may be exposed.**

- ***Environmental Signal*****: the electrical representation of an environment sensed via transducer or sensor.**
  - Replaced "Arming Signal" in previous presentations

- ***Sensor*****: A component or series of components designed to detect and respond to a specific environment.**

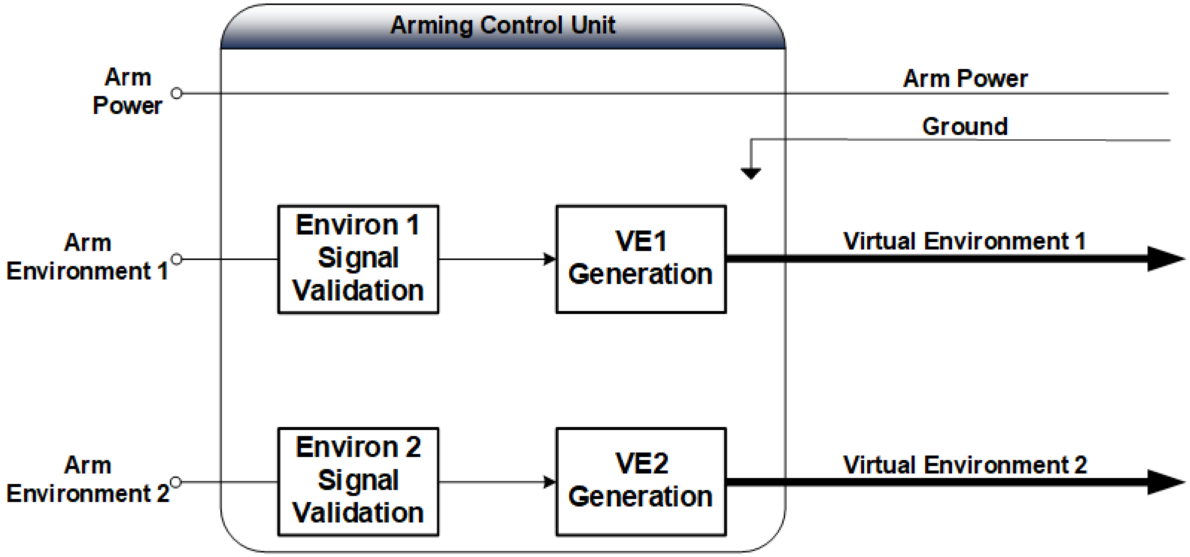
- ***Virtual Environment*****: A unique electrical signal derived or translated from an environmental signal sensed by the fuzing system. It is NOT a direct sensor output.**
  - Encompasses both analog and digital signals
  - VEs are a signal that is designed/engineered to be unique and robust.

Guidelines for the Arming Control Unit

(i.e. the Master S&A)

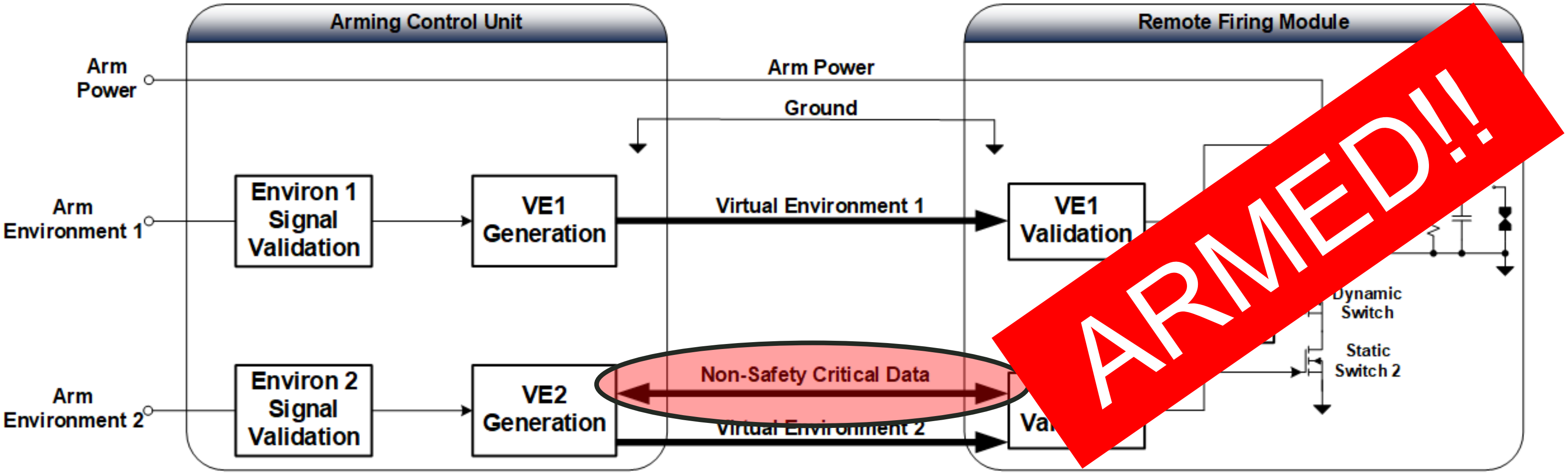
GUIDELINES

- **The Arming Control Unit (ACU) should directly sense, process, and validate at least one physical arming environment. The ACU should translate the physical arming environment(s) into Virtual Environment(s) (VE) and transmit all VE signal(s) to each Remote Firing Module (RFM).**



ACU GUIDELINES

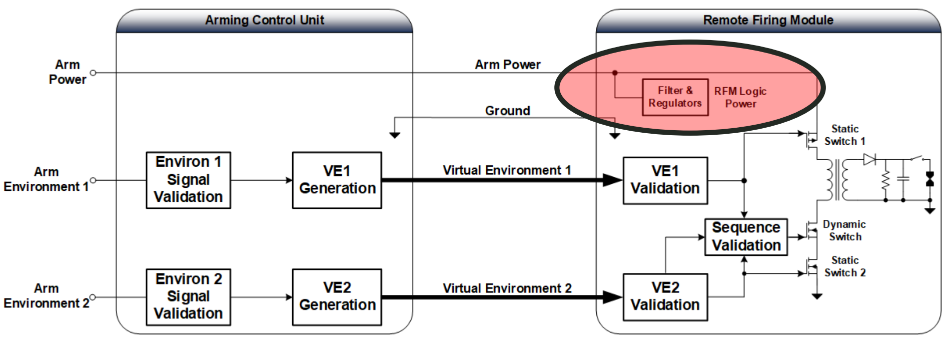
- **Based on system requirements, the ACU may maintain an active link with all RFMs that are in use after the fuze system is properly armed.**



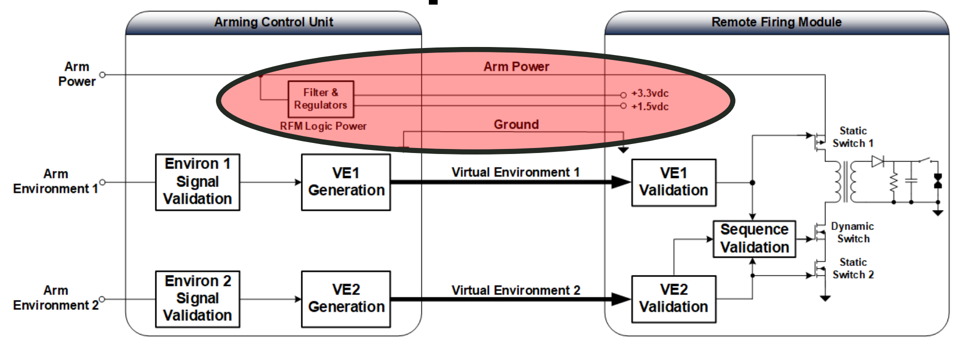
ACU GUIDELINES

- **The ACU is intended to provide all power and ground references for the RFMs including Arm Power where practical.**
  - Can also have the ACU *control* Arm Power to the RFM (ex. Option 3).

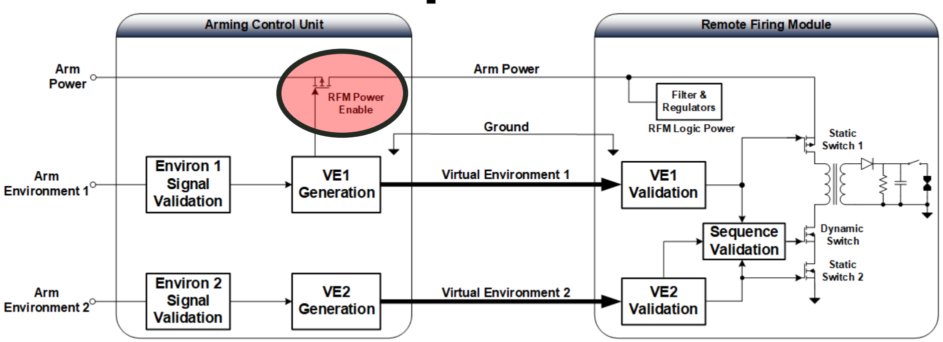
Option 1



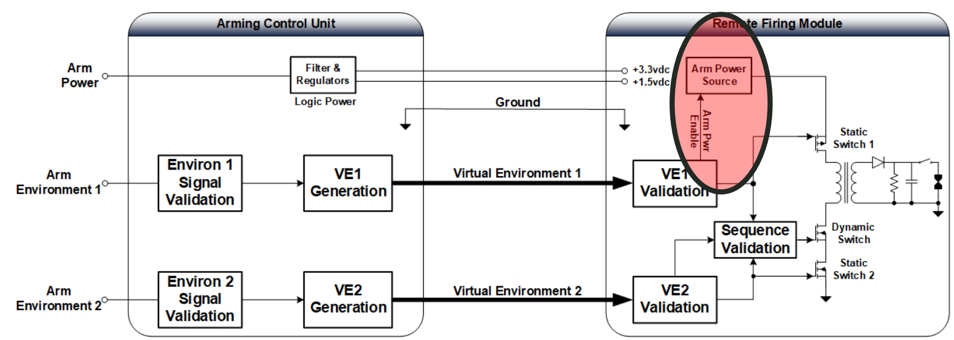
Option 2



Option 3



CONSULT!!!

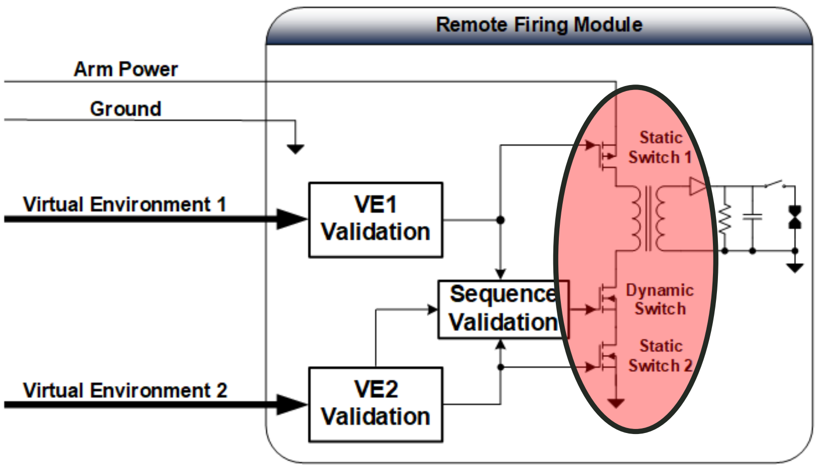


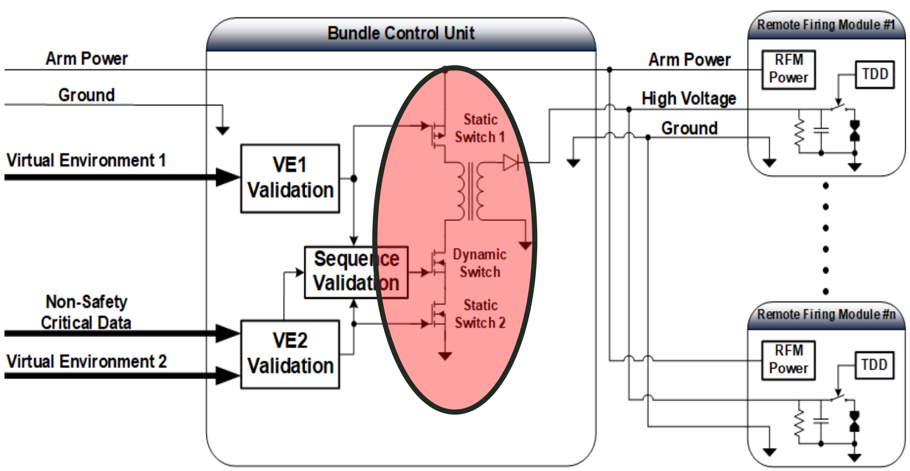
Guidelines for the Remote Firing Module

RFM GUIDELINES

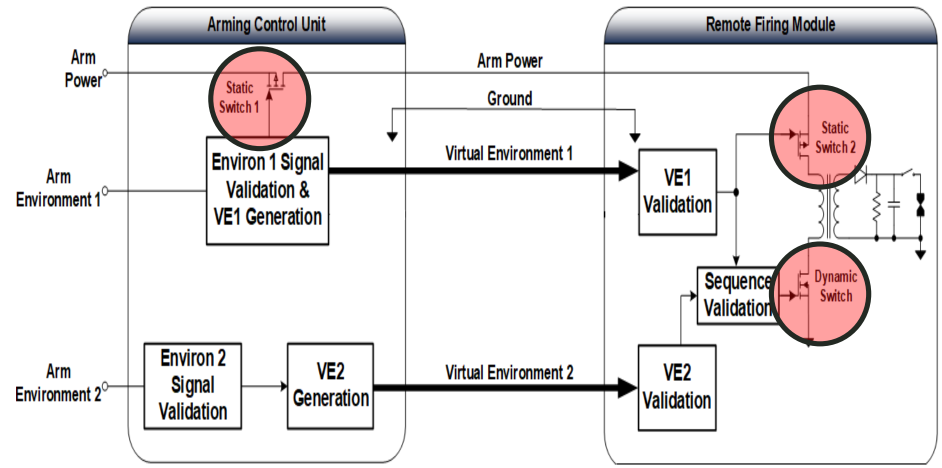
- **The RFM should contain all required arming switches.**

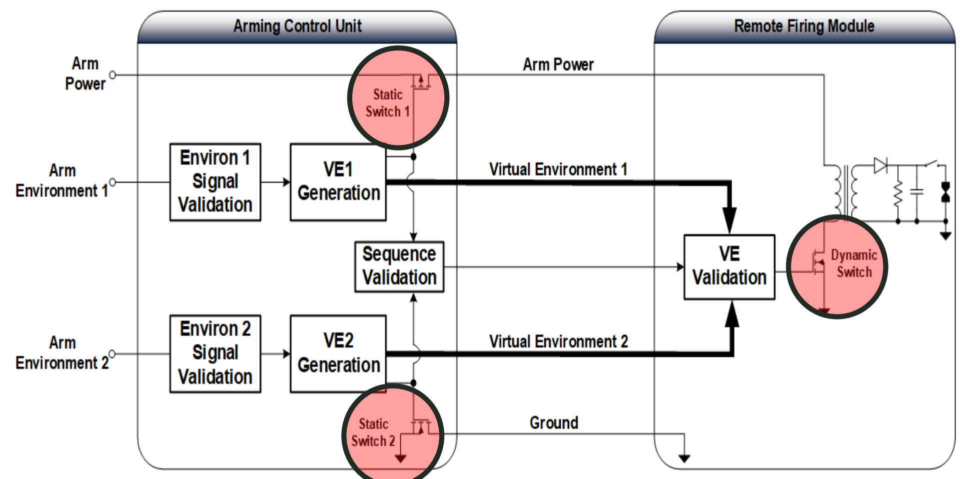
Compliant





CONSULT!!!





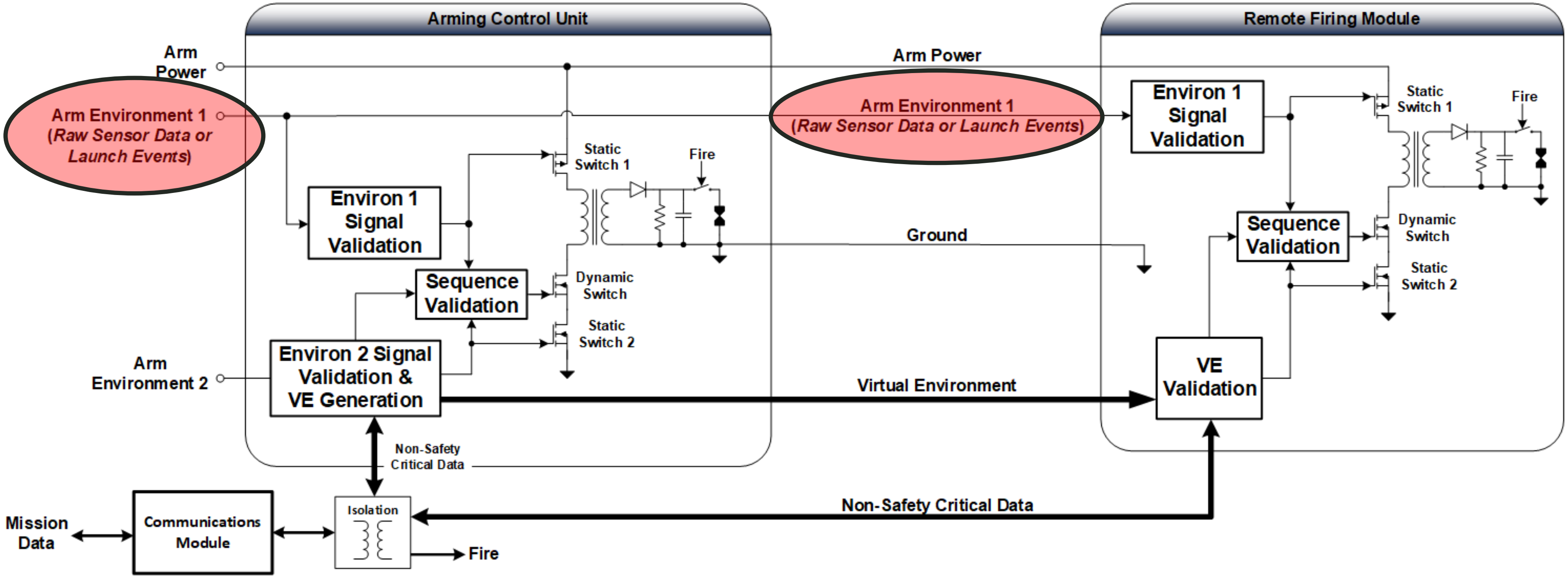
RFM GUIDELINES

- **Power to the safety critical features in the RFM should be applied as late in the launch sequence or operational deployment as practical.**
- **It is preferred that the dynamic signal for driving the high voltage transformer be generated within the RFM.**
- **Timing/Sequencing of the VE signals should be validated within the RFM.**
- **All Arm Delay Timers should reside within the RFM.**

Guidelines for Virtual Environment Signals & Messaging

VIRTUAL ENVIRONMENT GUIDELINES

- **There should be a minimum of two unique VE signals transmitted by the ACU to the RFM for proper arming of the fuze system.** ***A robust physical environmental signal (i.e., raw sensor data) may be used in lieu of one of the VE arming signals)*****.**

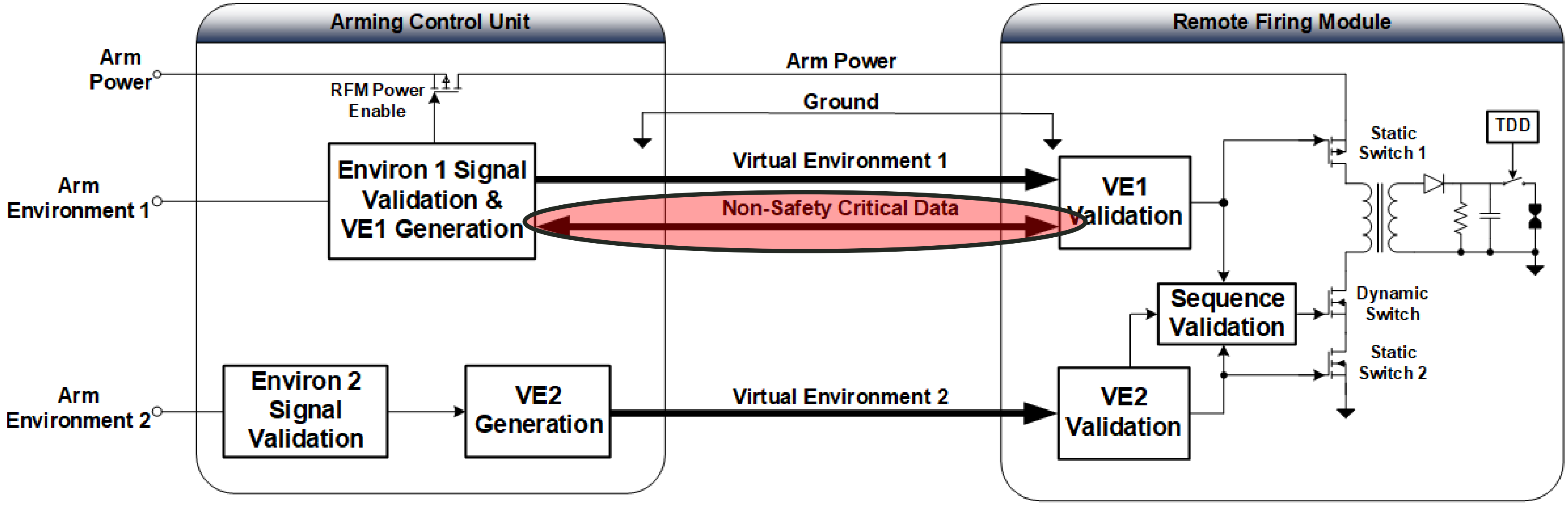


VIRTUAL ENVIRONMENT GUIDELINES

- **All environmental signals and VE signals must be robust such that the signal is not susceptible to inadvertent generation and subversion by credible environments anticipated in the lifecycle.**
- **Each VE signal should be generated by independent and dissimilar logic circuitry that is physically and functionally partitioned. The degree of dissimilarity should be sufficient to ensure that any credible common cause failure mode susceptibility will not result in an inadvertent arming signal transmission in other logic devices and circuits.**
  - This guidance also applies to the processing of the received arming signal at the RFM and subsequent activation of any safety features contained within.

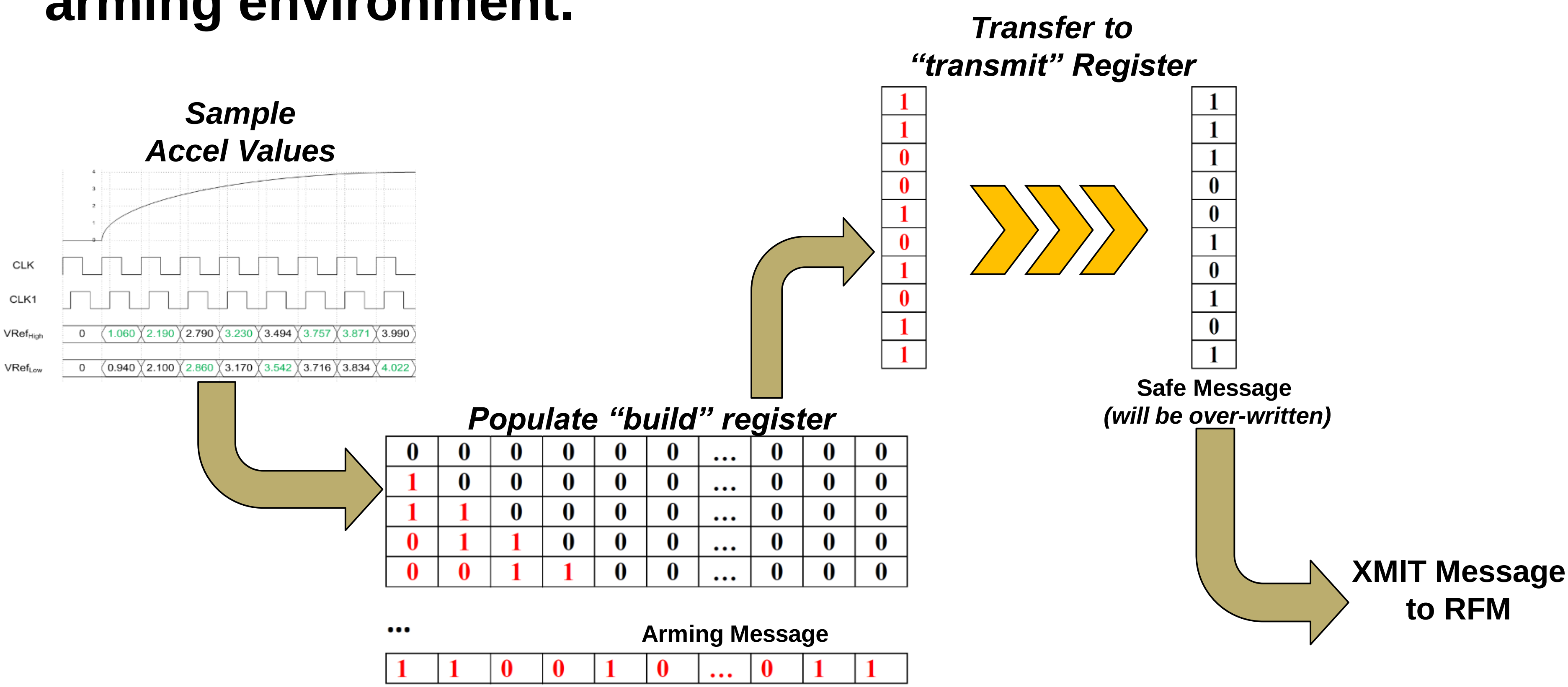
VIRTUAL ENVIRONMENT GUIDELINES

- **Each safety-critical VE message should be implemented as a dedicated, one-way communication line. All non-safety critical messages (e.g., polling, mission data, message acknowledgement, etc.) should be transmitted/received on a separate communication line..**



VIRTUAL ENVIRONMENT GUIDELINES

- **The preferred method is to dynamically generate the VE message based on events that occur throughout an arming environment.**



VIRTUAL ENVIRONMENT GUIDELINES

- **Where generation of the VE message is not practical, pre-stored VE serial messages may be utilized. The pre-stored VE message must be further distinguished by a minimum of two additional validation methods in order to prevent subversion of safety features by credible environments.**
  - Validation methods include but are not limited to…
    - *Sequencing/Sequence Number*
    - *Time Out*
    - *Feedback Message*
    - *Identifiers for sender & receiver*
    - *Alternating messages*
    - *Time Stamp*
    - *Message Reliability (i.e. CRC)*
    - *Flow Control*
    - *Replication*

NOTE: This method is considered a significant risk for acceptable implementation!!! Where operational requirements dictate the use of this method, sufficient justification will need to be provided. Consult with the appropriate SSA.

VIRTUAL ENVIRONMENT GUIDELINES

- **Each VE message should use strong data typing and be unique and unambiguous, from any and all other VE messages.**
  - Error detection schemes (e.g., parity, checksums, CRCs, etc.), if incorporated, must be distinct from any safety-critical message to the extent possible so as to not compromise the integrity of the message.
  - Error correction schemes will not be permitted.

VIRTUAL ENVIRONMENT GUIDELINES

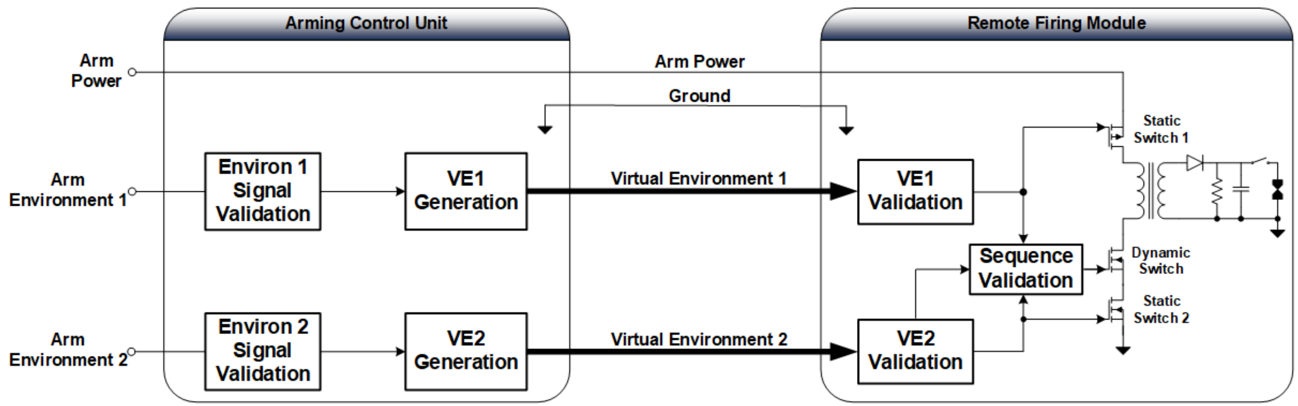
- **Tolerance to corrupt/invalid data should be characterized through analyses and tests. The analyses and test methodologies will be provided to the appropriate SSA for approval.**

Failure Mode	Definition
Inadvertent Release	A class of failures whereby a message is sent that is not a result of deliberate, planned actions
Incorrect Sequence	Messages are not received in the correct order
Early Arrival	The message is received correctly before it is expected
Late Arrival	The message is received correctly later than expected
Repetition	The same message is sent all the time (i.e., babbling idiot)
Deletion	All or part of the messages or message content is missing
Insertion	A message is received unintentionally and is perceived as the correct address (e.g., data from the wrong source)
Corruption	One or more data bits are changed in the message
Masquerade	A non-safety-related message could be interpreted as a safety-related message
Inconsistency	Two or more receivers have a different view of the transmitted data or the receivers may be in different states

Mitigation Method >>>>>>> / Failure Mode	Sequence number	Time Stamp	Time out	Message Reliability (e.g. CRC)	Feedback Message	Flow Control	Identifiers for sender and receiver	Replication	Alternating messages
Inadvertent Release	●	●	●		●				●
Incorrect Sequence	●	●							●
Early Arrival		●							
Late Arrival		●	●		●				
Repetition	●	●							●
Deletion	●	●			●				●
Insertion	●				●			●	●
Corrupted Message				●	●				●
Masquerade				●	●		●		
Inconsistency						●			

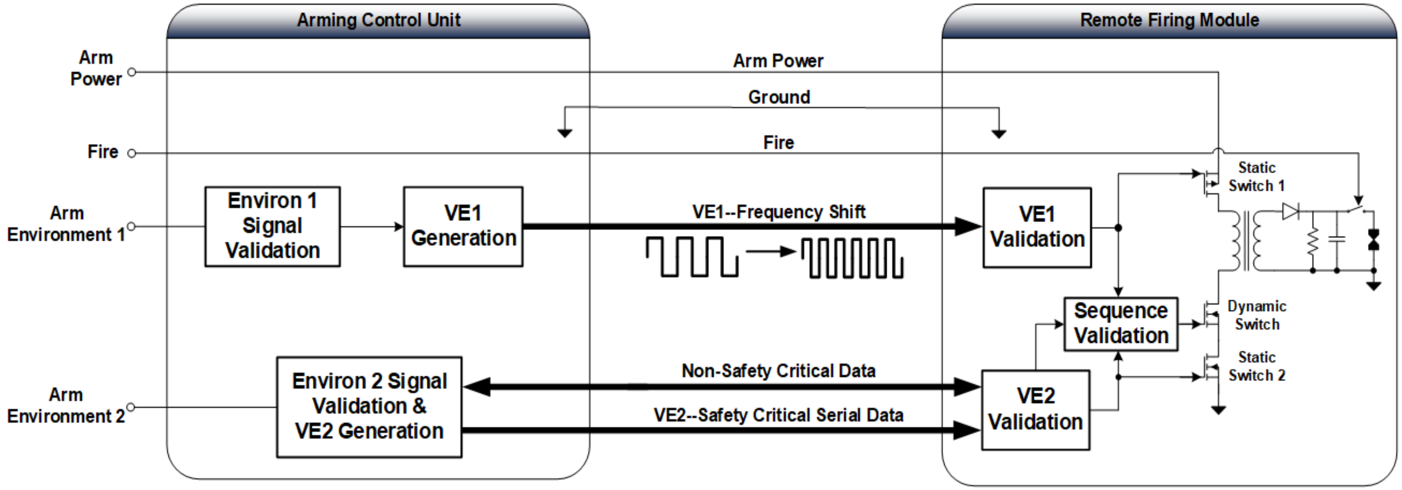
Low Voltage Command-Arm Architectures

FUNDAMENTAL BLOCK DIAGRAM



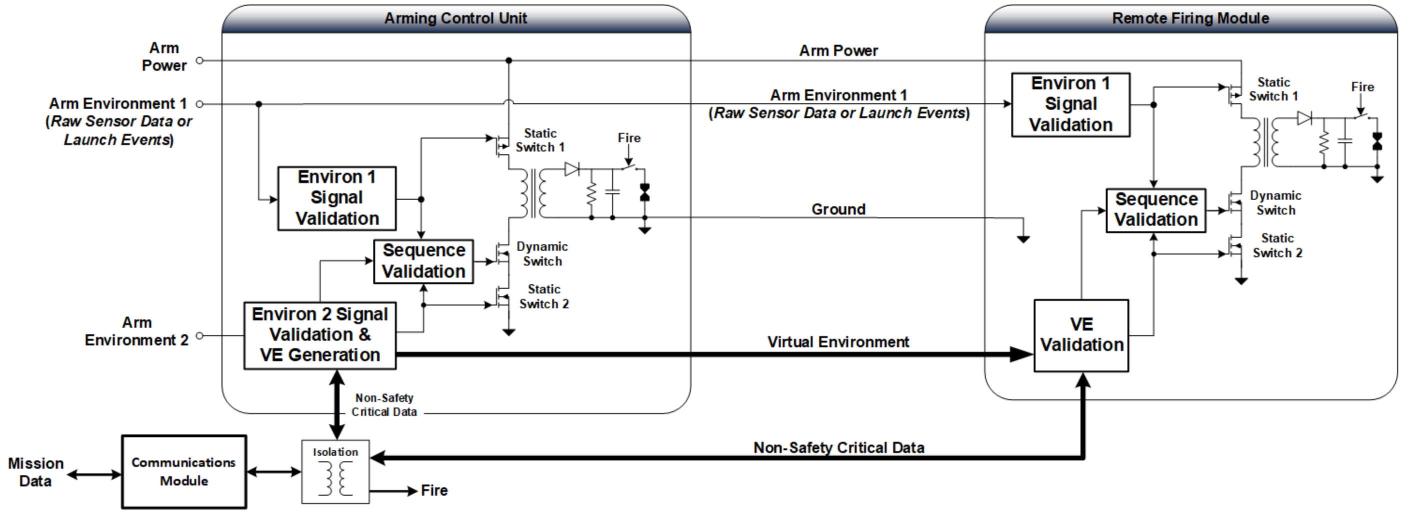
- The ACU “Environ Signal Validation” & “VE Generation” blocks and the RFM “VE Validation” blocks may be implemented with discrete components or complex logic.
- Non-Safety Critical Data (e.g., “Mission” Data) and the “Fire” signals are not shown due to the application-specific nature of these signals.

FREQUENCY SHIFT/SERIAL DATA BLOCK DIAGRAM



- An initial frequency is sent to the RFM at the beginning of the arming environment and is "shifted" to another frequency at completion of the arming environment. The RFM must detect this change in frequency within a specific time window for it to be valid.
- ***Signals Utilized:*** **Analog Square Wave, *Generated* serial message.**

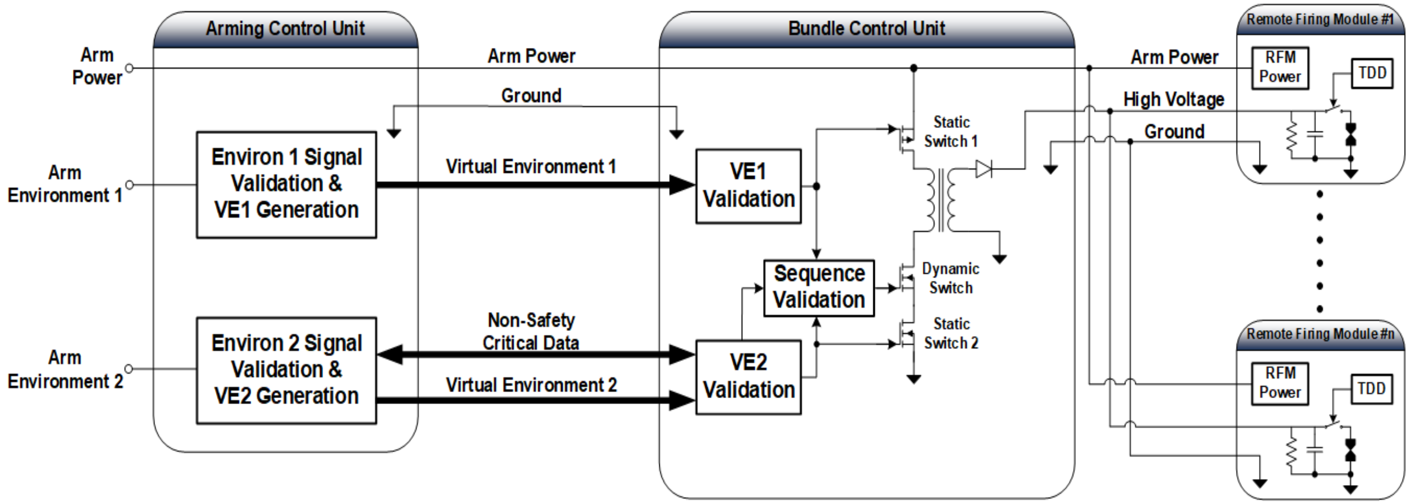
PHYSICAL & VIRTUAL (HYBRID) BLOCK DIAGRAM



- **This architecture utilizes a robust signal from a physical arming environment and a serial message as a VE. Note that the safety features are located in both the ACU and RFM.**

- ***Signals Utilized:*** **Raw sensor data, *Generated* serial message.**

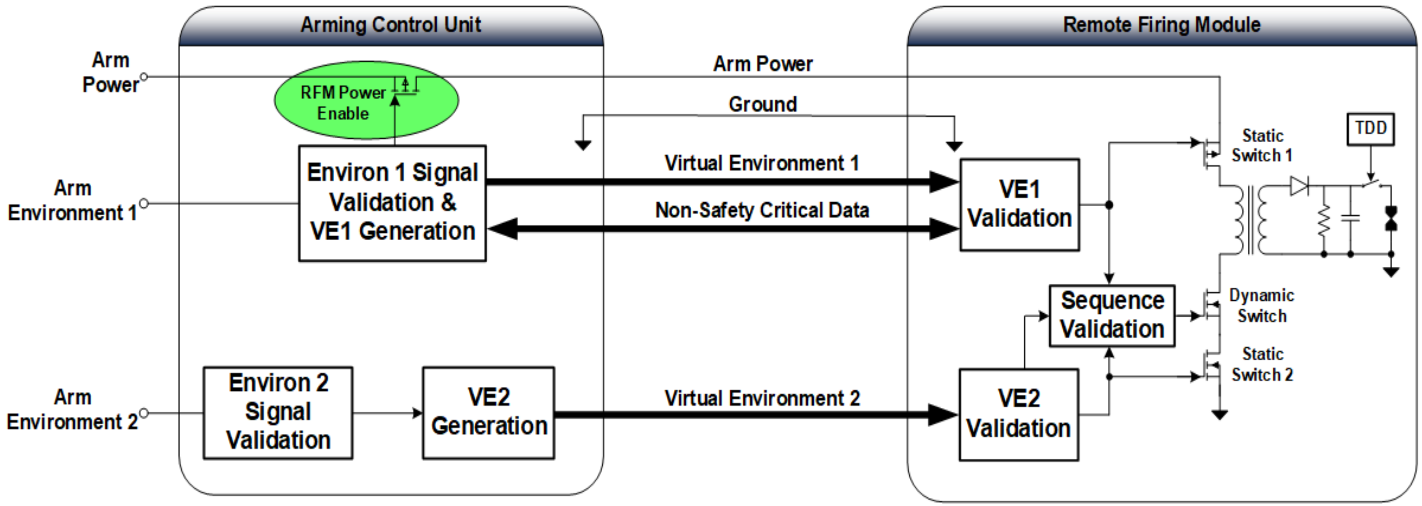
BUNDLE CONTROL BLOCK DIAGRAM



- This architecture utilizes a centralized safety module and distributes the firing voltage to the remote locations. The VEs are communicated between the ACU and Bundle Control Unit (BCU).

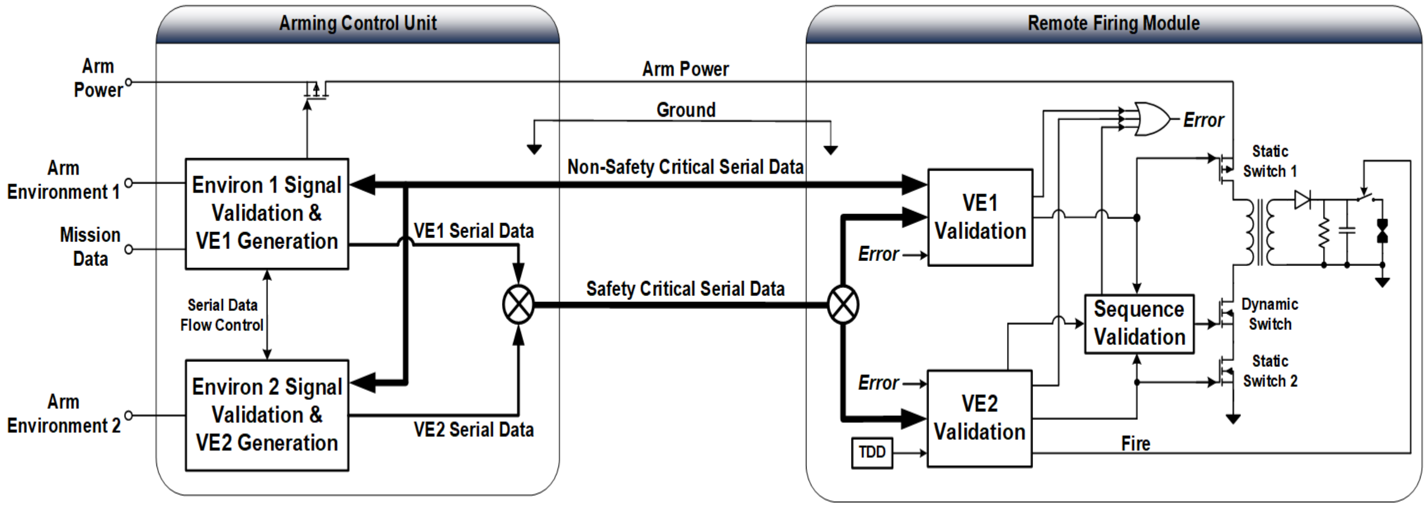
- *Signals Utilized:* Analog Square Wave (Frequency Shift), *Generated* Controller Area Network (CAN) *broadcast* message.

RFM POWER CONTROL BLOCK DIAGRAM



- This architecture utilizes a transistor switch to control power to the RFMs.
- ***IMPORTANT!!!:*** ***T*****his switch** ***is not*** **considered a safety feature and** ***does not*** **contribute towards the prevention of fuze arming.**

SINGLE SERIAL DATA LINE BLOCK DIAGRAM



- **In this architecture, both Virtual Environments are transmitted over a single serial data line.**

NOTE: This method is considered a significant risk for acceptable implementation!!! Where operational requirements dictate the use of this method, sufficient justification will need to be provided. Consult with the appropriate SSA.

REFERENCES

- ***Probability of Inadvertent Arming Due to Noise for a Distributed S-A using a Single Serial Data Line*.**
  - Randall Cope, Navy-China Lake; 5 February 1999
- ***Safety of Digital Communications in Machines***
  - Jarmo Alanen et al; VTT Industrial Systems, 2004
- **Validation of Communication in Safety-Critical Control Systems**
  - Jacques Herard et al; Nordtest Technical Report 543; October 2003
- **IEC 61508 – Functional Safety of Electrical Safety-Related Systems**

ALWAYS REMEMBER...WE ARE WITH THE GOVERNMENT AND WE ARE HERE TO HELP!!

QUESTIONS???


You know it's true!!!


I SURVIVED ANOTHER MEETING THAT SHOULD HAVE BEEN AN EMAIL

Close-Air-Support with <190 Rounds… A Practical Approach

L. Schumacher[1] R. Barrett[2]

[1] PhD Student, University of Kansas

[2] Professor of Aerospace Engineering
Adaptive Aerostructures Laboratory Director

National Defense Industrial Association

62nd Annual Fuze Conference, 2019

Overview

- Introduction
  - Conventional CAS
  - Guided Hard-Launch Munitions
- MASS Con-ops
- Retrofit Capability
- Future Airframe Design Implications
- Conclusions & Future Work

Close air support (CAS) is air action by fixed-wing and rotary-wing aircraft against hostile targets that are in close proximity to friendly forces and requires detailed integration of each air mission with the fire and movement of those forces

-DOD Joint Publication 3-09.3

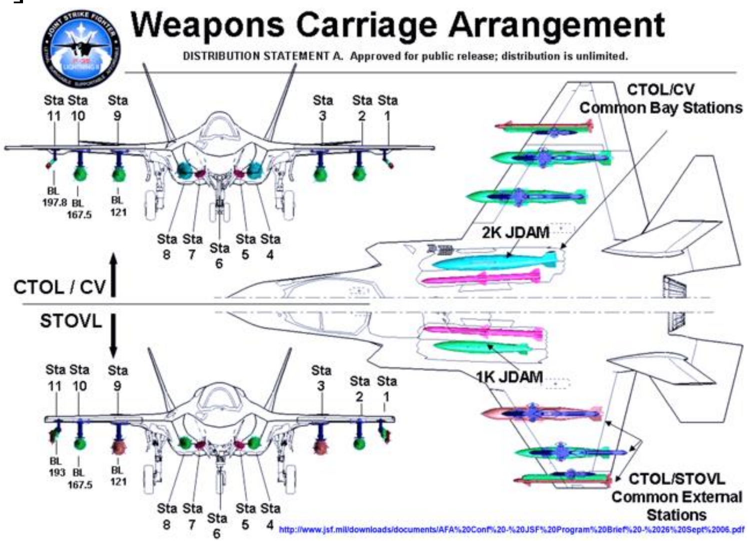
[1]

[2]

Current emphasis on stealth and BVR engagement…

- Air-to-air mission
  - 14 x AIM-120
  - 2 x AIM-9
  - 180 x 25mm (~3 sec.)
- Air-to-surface loadout
  - 2 x AIM-120
  - 6 x GBU-31 JDAM
  - 2 x AIM-9X
  - 180 x 25mm (~3 sec.)

[3]



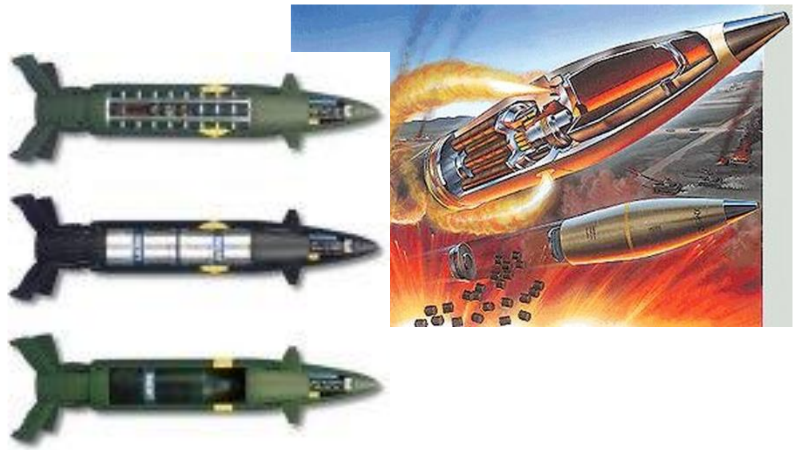
F-35 integration into a close-air-support (CAS) role

Design Philosophy: make every round count

- Increase P_{hit} / $P_{k/hit}$
- Increase energy at target impact
- Increase effective range

Thanh Hóa Bridge, 1972
873 air sorties... Vs 4 w/LGBs

M712 Copperhead 1975

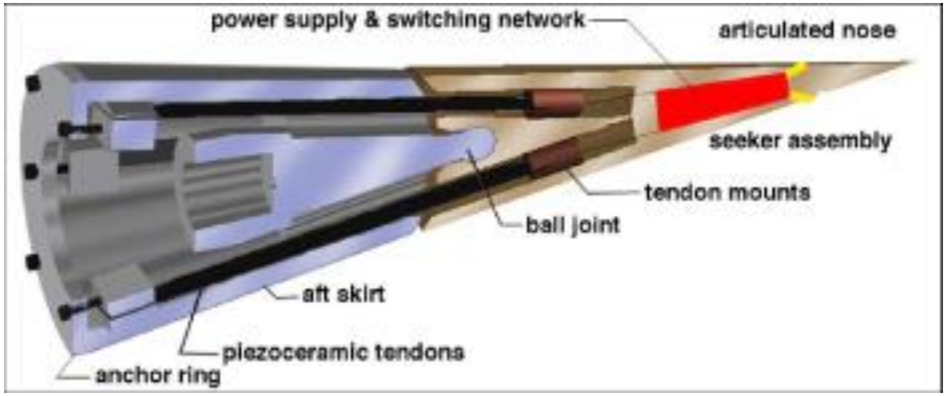


XM 982 Excalibur
& ERGM

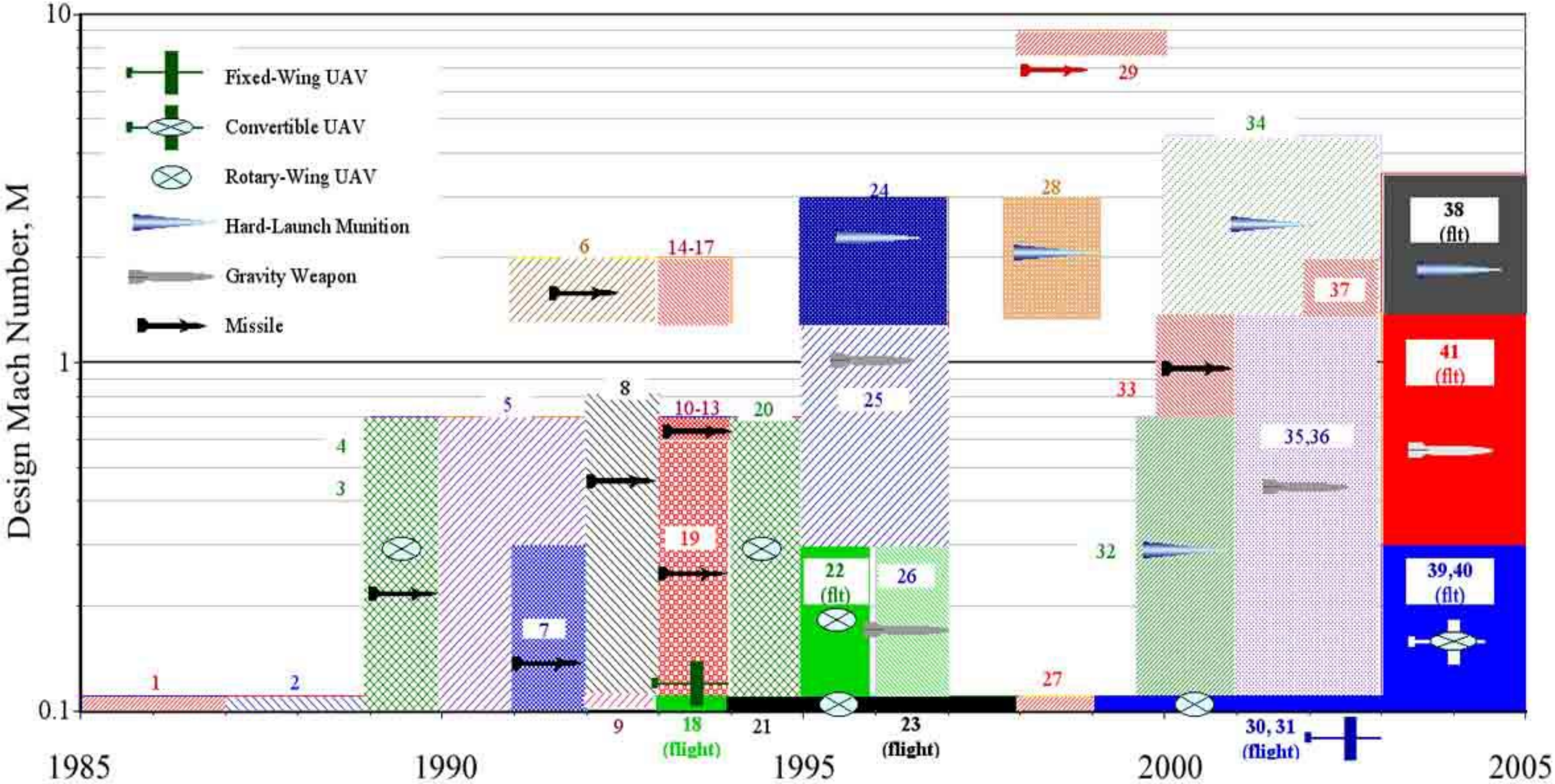
Barrel-Launched Adaptive Munition (BLAM) Program 1995 - ‘97

USAF/AFRL-MNAV

- Aerial Gunnery (20 - 105mm)
- Extend Range w/2g maneuver
- (Eglin AFB tests ‘97)
  (Mach 3.3 tests ‘96-’97)
- Increase hit probability
- Increase probability of a kill given a hit
- Reduce total gun system weight fraction

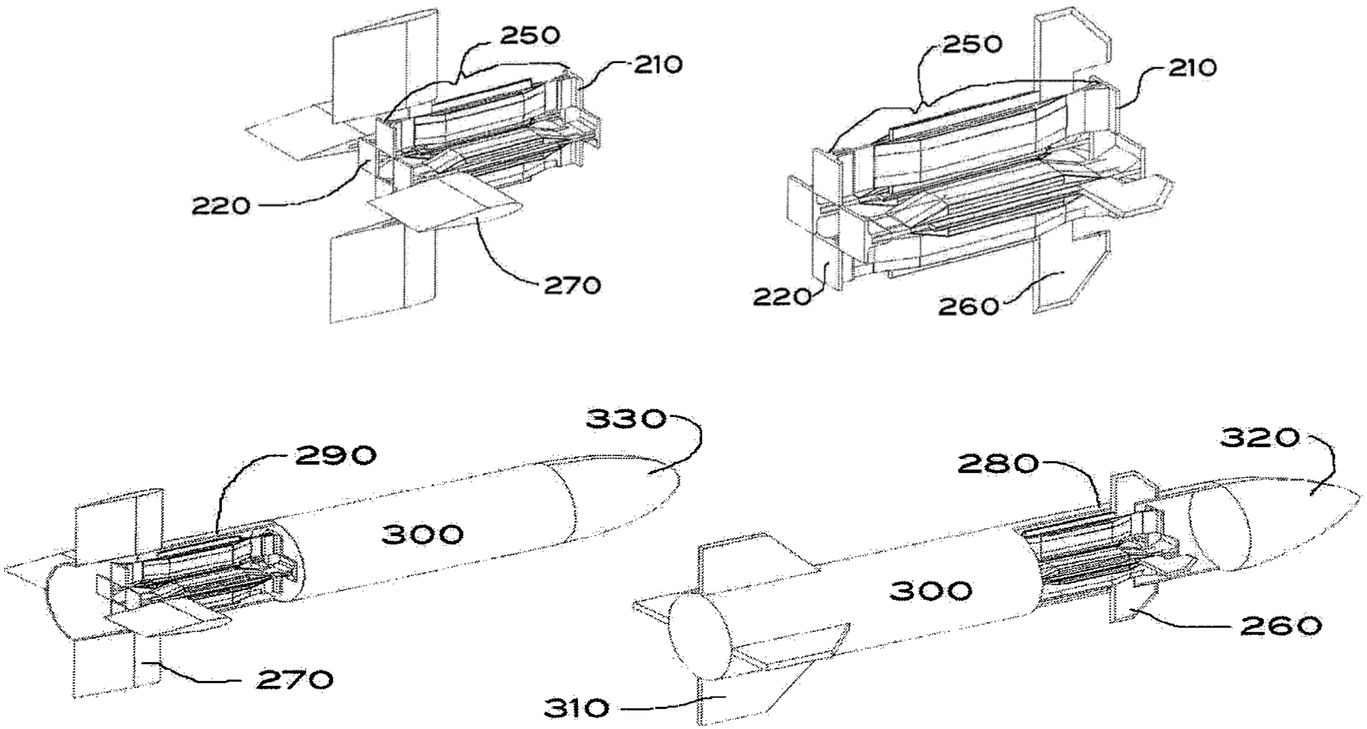


AAL: Building Adaptive Actuators for Hard-Launch Munitions since 1995

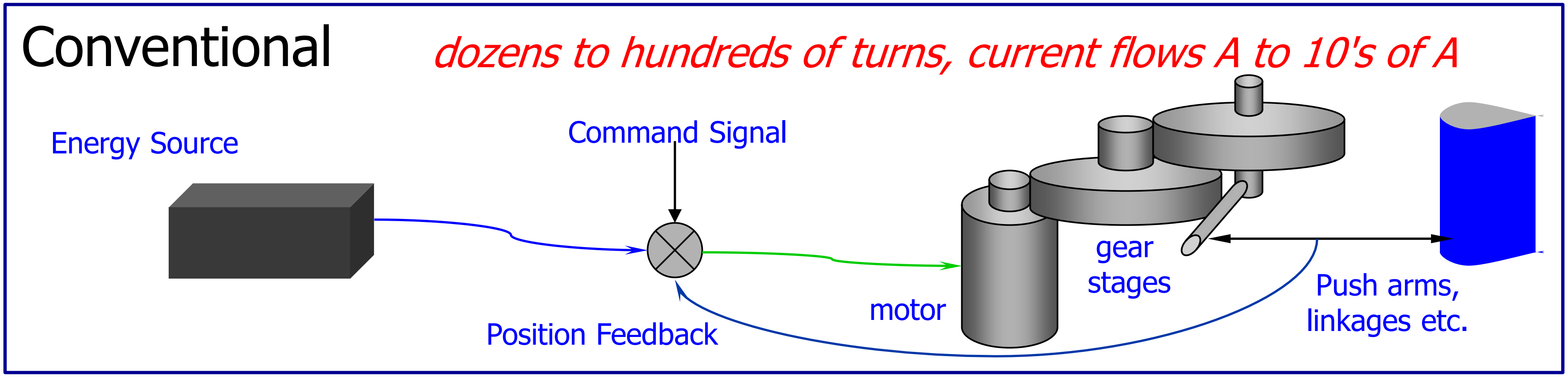


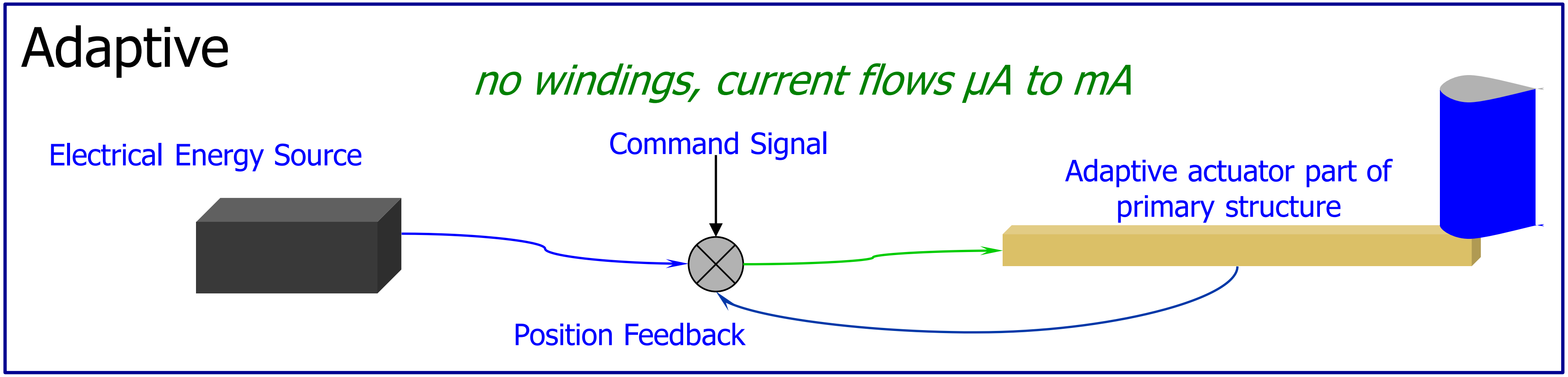
AAL: Issued patents & 2 decades of test data up to: Mach 11 & 100,000g’s

PBP-Class Hard-Launch Capable Actuator FCS Units:

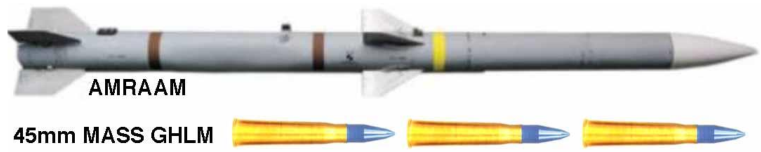


AAL: Building the World's fastest fully proportional hard-launch flight control actuators

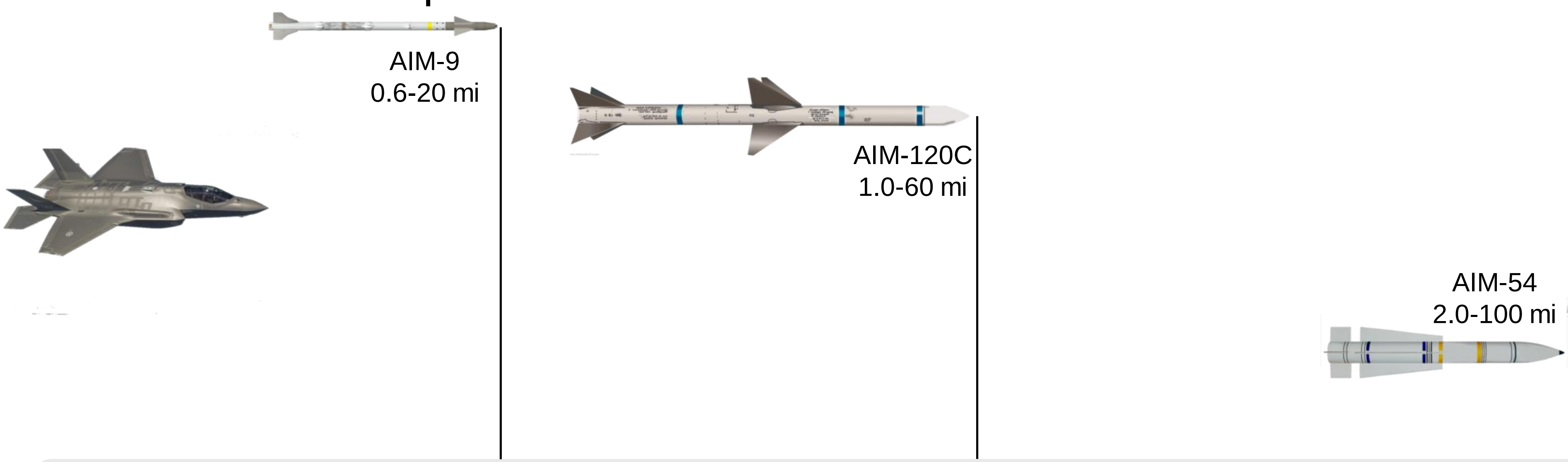




GHLM Potential

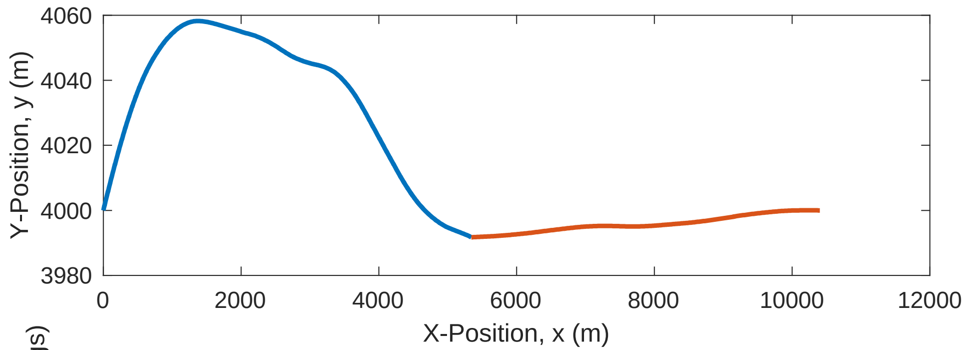


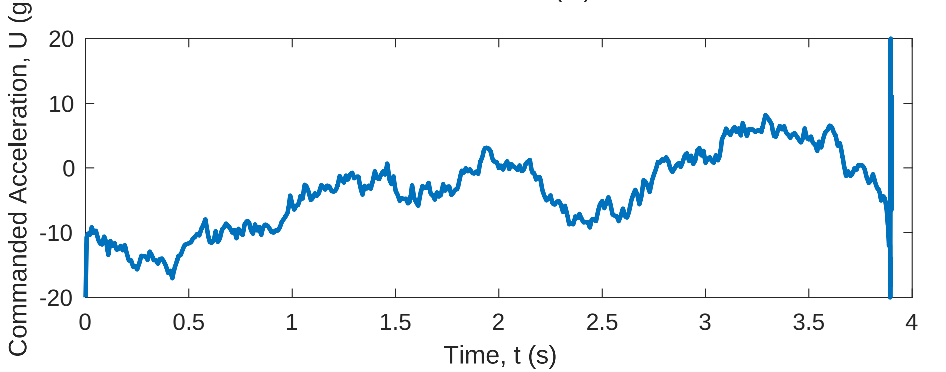
- Increased Number of Targets
- Expanded Engagement Range Envelope
- Airframe Defense with Maneuver Overmatch
- Decreased Cost per Kill

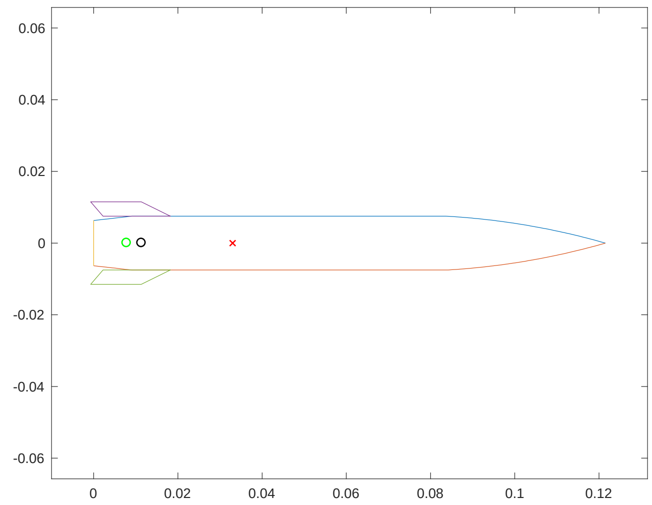


Guided Hard-Launch Munitions
0-100+ mi

➢Maneuver specification: real atmosphere





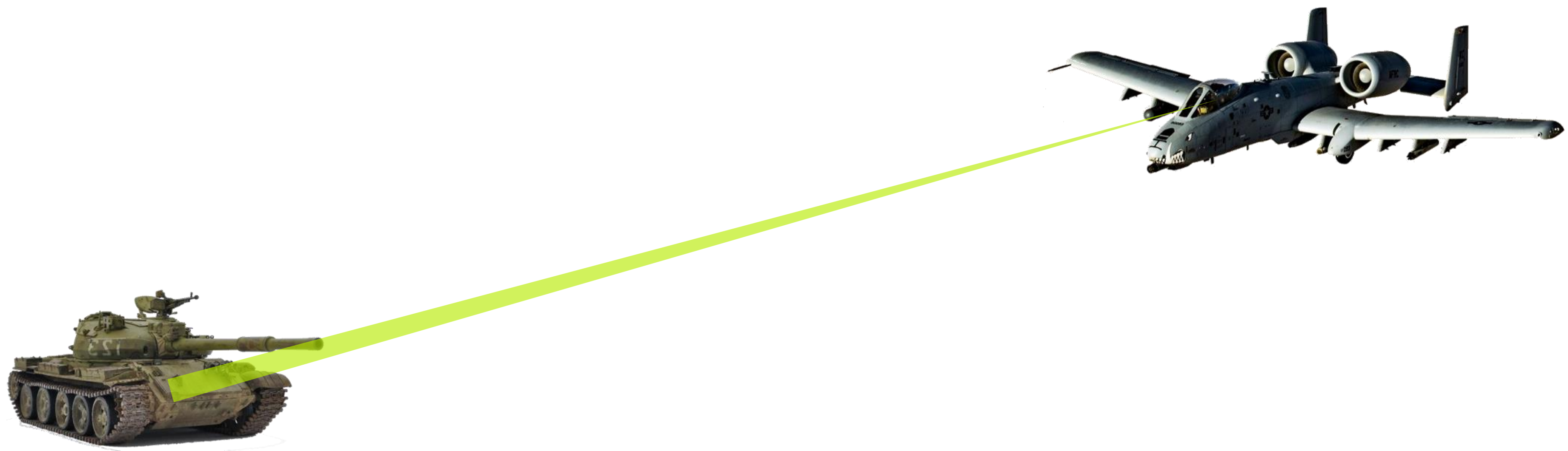


$$\Phi_w(\omega) = \frac{2\sigma_w^2 L_w}{\pi V} \frac{\left(1 + \frac{8}{3} * \frac{2.678 L_w \omega}{V}\right)^2}{\left(1 + \left(\frac{2.678 L_w \omega}{V}\right)^2\right)^{\frac{11}{6}}}$$

$$\frac{d\bar{V}}{dt} = -\frac{\rho V S C_D}{2m}\bar{V} + \frac{\rho S C_{L_\alpha}}{2m}\left(V^2\hat{x} - (\bar{V}\cdot\hat{x})\bar{V}\right) + \bar{g}$$

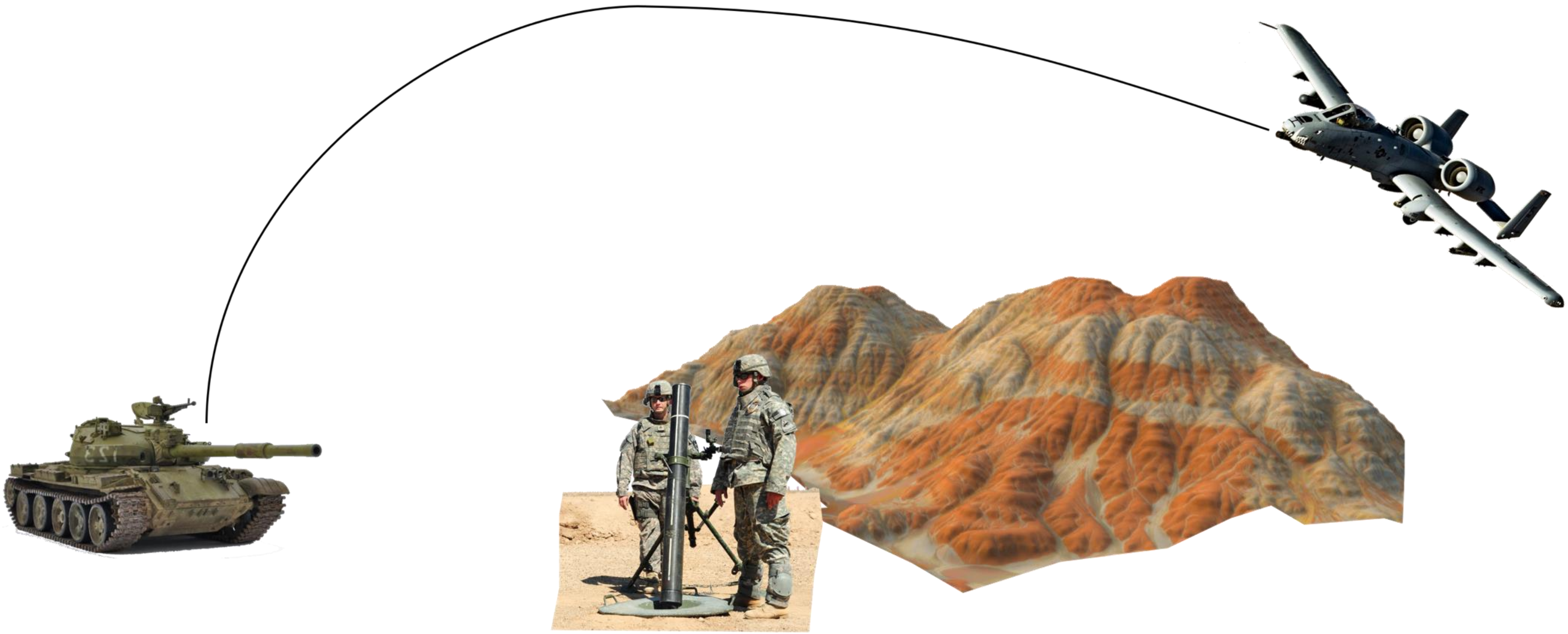
$$\frac{d\bar{h}}{dt} = \frac{\rho V S d^2 C_{l_p}}{2I_y}\left(\bar{h}\cdot\hat{x}\right)\hat{x} + \frac{\rho V^2 S d \delta_F C_{l_\delta}}{2I_y}\hat{x} + \frac{\rho V S d C_{M_\alpha}}{2I_y}(\bar{V}\times\hat{x})$$

- Increase impact kinetic energy at Effective Range:
  - PGU-14 E_{impact}/E_{muzzle} ~ 50%
  - MASS GHLM E_{impact}/E_{muzzle} ~ 90%
- MASS Guided Variants



MASS Guided Indirect Fire

- Semi-ballistic path
- Terminal Guidance



- ➢MASS GHLM IR defense
  - ➢Flying “flare”

- ➢MASS GHLM RF defense
  - ➢Kinetic kill
  - ➢Proximity with debris field

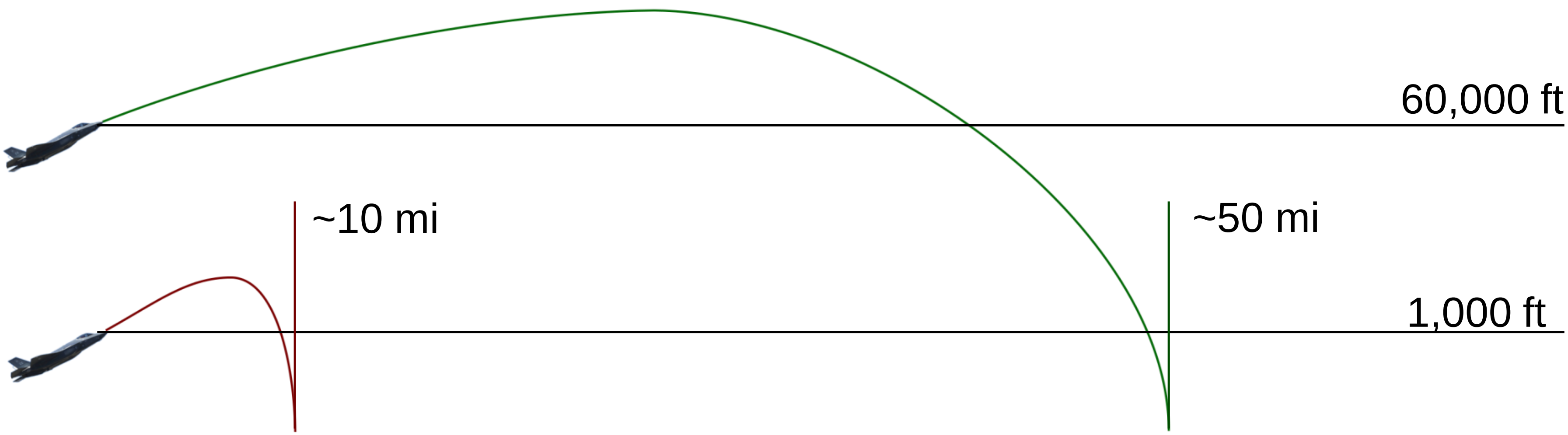
- Conventional F-35A
  - 180 x 25mm (~3 sec.)
  - ~$32,000 per flight hour
  - 14 x hardpoints + bays
- Conventional A-10
  - 1,174 x 30mm (~18 sec)
  - $11,500 per flight hour
  - 11 x hardpoints

[4]

[5] [6]

➢Retrofit of conventional rounds for GAU-22

	A-10 (PGU-14/B)	F-35 (PGU-32)	MASS F-35
Projectile Mass (kg)	0.425	0.18	0.25
Kinetic Energy on Target	100%	56%	**109%**
E_{target}/E_{muzzle}	47.7%	39.3%	**85.8%**



MASS retrofit of conventional rounds for GAU-22

- Effective up-gunning of F-35 without airframe modification
- Guidance of rounds and MASS lends near A-10 like capability

	P_h*P_k	Rounds/Target	Max Targets Engaged
A-10**	0.082	35	34
F-35A	0.050	58.9	3
MASS F-35A	0.342	7.2	25

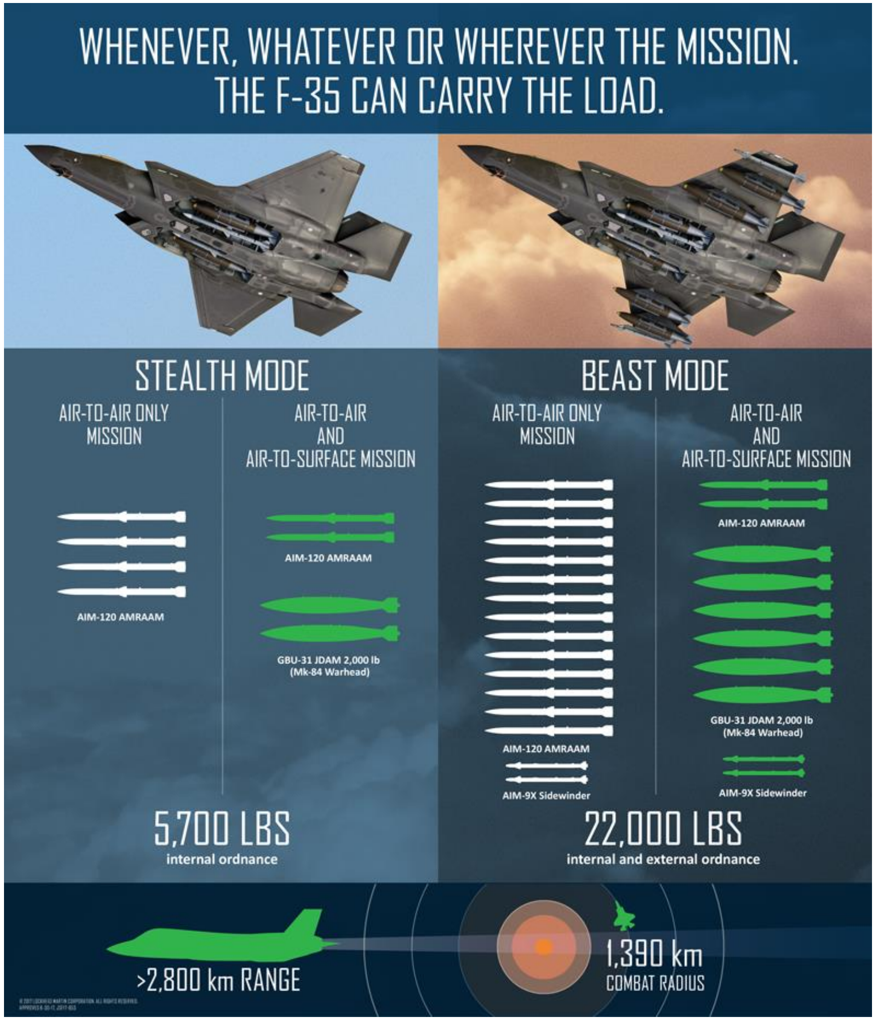
**Estimated assuming 0.5s per target

- Reduced Observables (RF, IR & Acoustic)
- Increased Airframe Performance
  - Reduction in platform weight, wetted area, and total volume

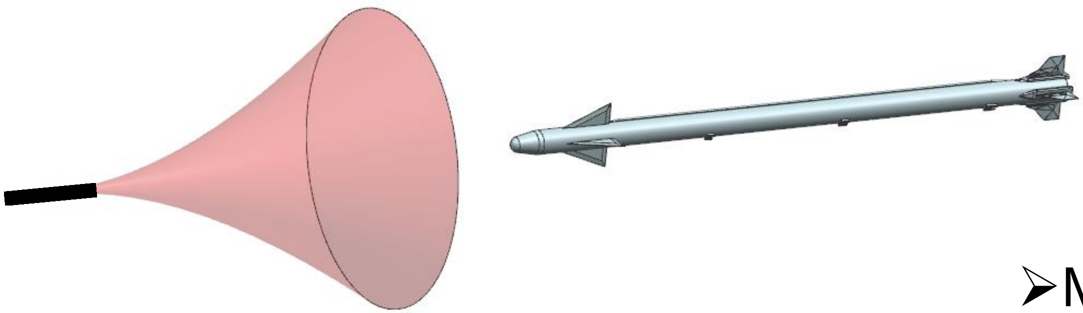
- Max 14 lightly armored targets with P_k assumed 99%
- Assume same airframe configuration and engine

Live atmosphere simulations of guided munitions show to achieve 14 kills at $P_k = 0.99$ at 50 miles:

- 45mm round with $V_m = 1065$ m/s
- $P_{hit} = 0.295$, 13.2 rounds per target to achieve $P_k = 0.99$
- 212 rounds required with no additional munitions (missiles, etc.)



[7]



- Kinetic kill
  - Scaled from PGU-28 as a function of mass of target to mass of projectile ratio

$$N = \frac{\ln(1 - P_{k,desired})}{\ln(1 - P_{k,projectile})}$$

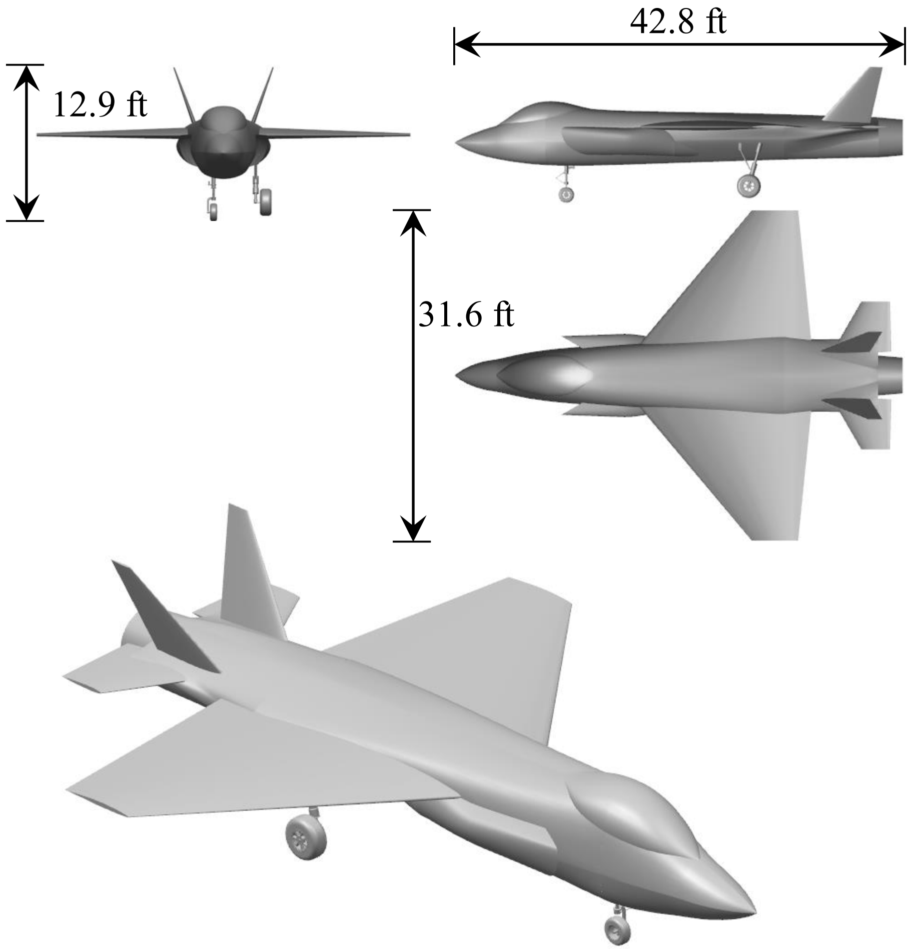
- Miss radius for P_k of 99%
  - Scaled from missiles with mass ratio of warhead and hydraulic diameter ratio
  - Assumed fragmentation size similar to PGU-28 and distributed evenly through explosive cone

[8]

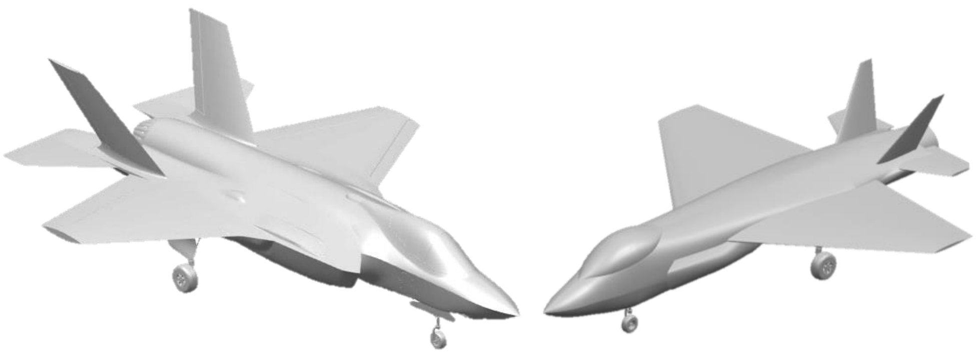
$$P_{k,projectile} = \mathrm{Pk}_{\mathrm{PGU28}} * (MR_{target})(MR_{projectile})$$

$$V_{fragment} = \sqrt{2E}\left(\frac{m_{metal}}{m_{charge}} + \frac{1}{2}\right)^{-\frac{1}{2}}$$

Roskam aircraft design methods through Class II



Parameter	F-35A	XF-36	% Change
MGTOW (lb)	70,000	57,000	-19%
Wing Area, S (ft^2)	447	375	-16%
Stealth Payload Required (lb)	5,700	1,171	-79%
Stealth Targets Engaged	4	14	250%
Max Range (nmi)	1,200	1,200	0%
Max Speed, Mach	M 1.61	M 1.79	12%



- Reduction in RCS
- Increased volumetric efficiency
- Maintain stealth with no bay door requirements
- Potential for aft barrel
- Defensive engagement capable
- Increased variety of targets engaged (attack and fighter roles)

Roskam aircraft design methods used for both aircraft, then scaled based on F-35A procurement cost per airframe. Assumed full batch 1768 airframes at uniform price.

Program Level Costs ($ billions)		
	F-35A	XF-36
RDT&E Total	$25.5B	$13.6B
Manufacturing Cost (Program)	$110.4B	$82.2B
Acquisition Cost	$115.9B	$86.3B
Program Operating Cost	$235.5B	$225.5B

Airframe Level Costs		
	F-35A	XF-36
Unit Price (millions)	$ 80.0M	$ 56.5M
Operating Cost per Flight Hour	$ 29,600	$ 28,400

For every $1 spent on GHLM RDT&E for aerial gunnery…

2 orders of magnitude in launching platform lifecycle cost savings

- Significant fleet multiplication possible
- Apparent caliber increase for retrofit of existing systems
- Future airframe design performance benefits

Enabling Technology: MASS

- Secure commercial partner for MASS tech. transfer
- Work with commercial partner to capture aerial munitions market

The University of Kansas
Department of Aerospace Engineering

The Madison and Lila Self Graduate Fellowship

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Questions

Munitions Batteries

62nd NDIA Annual Fuze Conference
Hyatt Regency, Buffalo, NY

Lithium Battery Innovations For Projectile Munitions

May 13-15, 2019

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Munitions Batteries

Agenda

- Applications
- Battery Characteristics
- Electrochemistries
- Challenges
- Innovations
- Performance Characterization
- Selected Cells
- Selected Batteries
- Summary

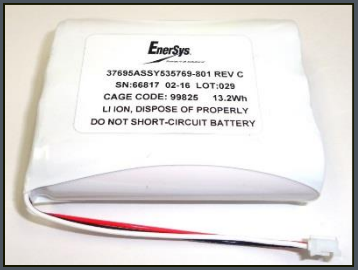
Li-Ion FTS Battery
(Device No. G3203B1)

Munitions Batteries

Whether your application is on the Land, Sea, Air, or Space, EnerSys can provide the power.

Lithium Batteries

Battery Characteristics



Li-Ion Battery

Why use Lithium Batteries?

1. Long Shelf Life

Lithium reserve batteries are unique in their ability to last for over 20 years prior to activation. This long shelf life is made possible by either storing the active materials separately until activation or by storing the active materials in a non-ionically conductive state until activation.

2. Temperature Range

Capable of operation across the full military temperature range (-65˚F to +221˚F/-54˚C to +105˚C).

3. Environmentally Hardened

Our lithium reserve batteries are optimized for operation in high acceleration environments (up to 100,000 g’s) and high spin rate (30,000 RPM), applications that ordinary batteries cannot survive.

Munitions Batteries

Battery Characteristics

Thermal Batteries

Lithium Alloy / Metal Disulfide Molten-Salt Power Sources

- Achieve dormancy by storing the electrodes in a non-ionically conductive state until deployed.
- Batteries can achieve activation within hundreds of milliseconds.

Characteristics in Common

- Self-contained
- Hermetic
- Reserve primary
- Lithium power sources
- Capable of being stored in excess of 20 years
- Activated on demand or by the conditions of deployment.
- Operation over the full military temperature range.

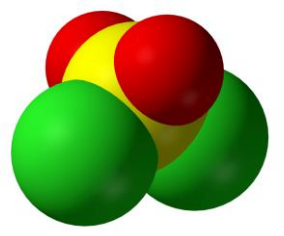
Ambient Temperature Batteries

Lithium / Oxyhalide Power Sources

- Achieve dormancy by physically separating the active components, I.e., the lithium foil anode and the thionyl chloride electrolyte.
- Cells and batteries can achieve activation within milliseconds and then provide power and deliver energy to support mission requirements.

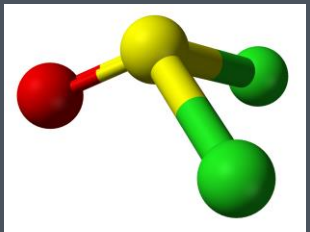
Lithium Batteries

Electrochemical Systems



Products Offered

- Lithium Thermal Batteries
- Lithium Ambient Temperature Batteries
- Lithium-Ion Rechargeable Batteries



Electrochemical Systems

- Lithium Silicon/Cobalt Disulfide ($LiSi/CoS_2$)
- Lithium Silicon/Iron Disulfide ($LiSi/FeS_2$)

High Power Density

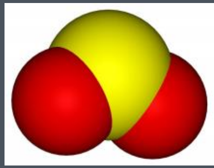
- Lithium/Thionyl Chloride ($Li/SOCl_2$)
- Lithium/Sulfuryl Chloride (Li/SO_2Cl_2)

High Energy Density

- Lithium/Sulfur Dioxide (Li/SO_2)
- Lithium/Vanadium Pentoxide (Li/V_2O_5) — **Fast Activation Cold Temperature**
- Lithium-Ion (various chemistries) — **Rechargeable**

Automated Manufacturing

- Multiple automated manufacturing lines are used to produce Ambient Temperature Batteries and Thermal Batteries.



Munitions Batteries

Activation Methods


Miniature Piston Actuator

- Batteries can be activated on demand or by the conditions of deployment, such as: ballistic launch, aircraft release, or canister dispense, etc. using one or more of the following methods:


Electric Igniter


M42C Percussion Primer

Method	Initiation
Electric Igniter	Electrical Pulse
Electric Primer	Electrical Pulse
Percussion Primer	Firing Pin, Lanyard
Stab Initiated	Squib, Thumb Screw
G-activation	Launch Acceleration, Target Impact


Dashpot Electrolyte Reservoir


Pyrotechnic Gas Generators

- Batteries can be activated within milliseconds to seconds.

Munitions Batteries

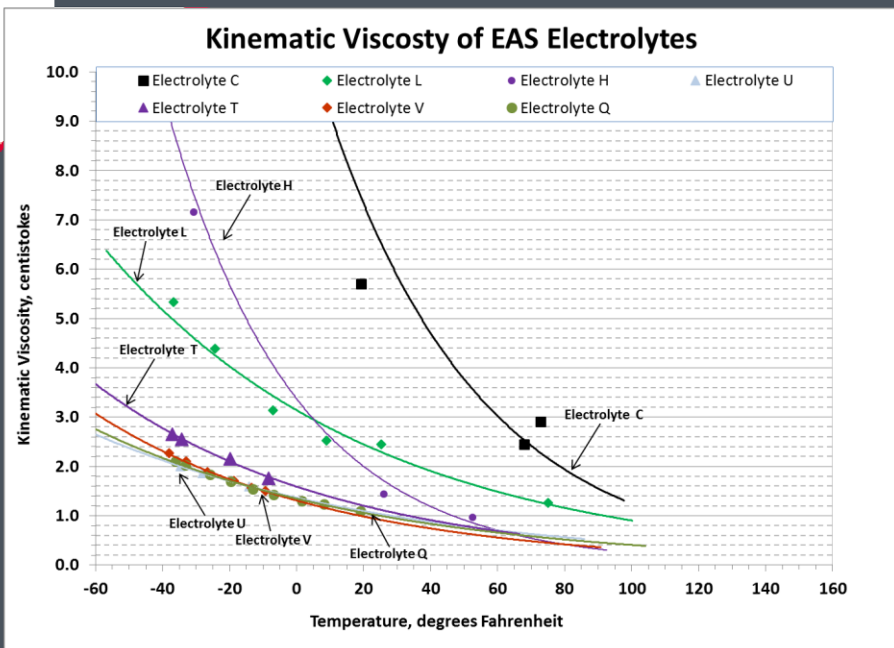
Challenges

	Requirement		Potential Solution
Activation Risetime	Faster Initiation	→	Lower Viscosity Electrolytes
Cold Temp. Performance	Improved Function Cold	→	Electrolytes with Greater Ionic Conductivities
Power Capability	Greater Power	→	Lower Cell Impedance
Deliverable Capacity	Greater Energy	→	Increased Active Material Content

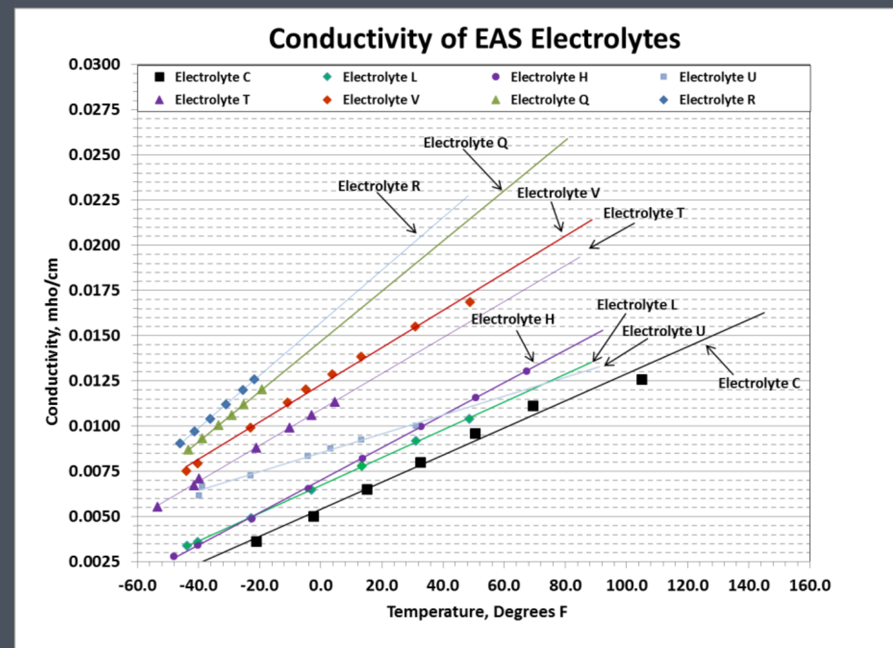
Munitions Batteries

Innovations

Advanced Electrolytes for Improved Cold Temperature Operation



Lower Viscosity Electrolytes



Greater Ionic Conductivities

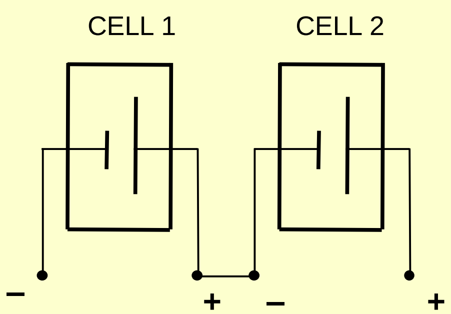
New electrolytes are stable for 20+ year storage! Enhanced cold temp Conductivity and Viscosity give excellent rise time and voltage performance.

Munitions Batteries

Battery Configurations (Liquid Reserve Primary)

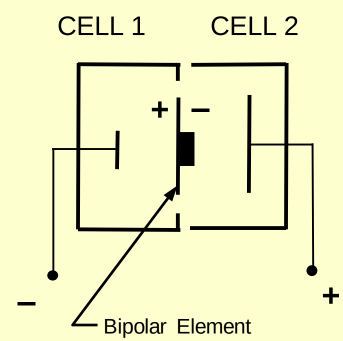
What’s the best configuration?

Long Mission Life
High Energy



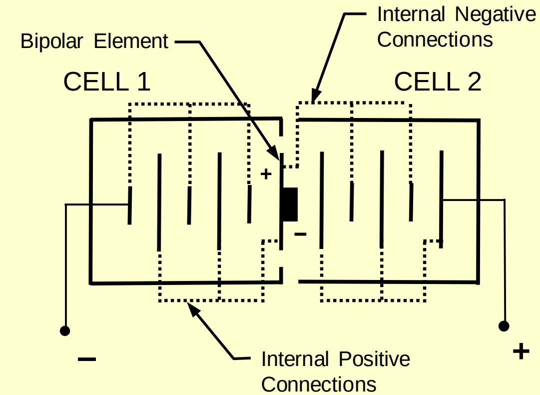
Discrete Unit Cells
Cells consisting of one set of electrodes.

Moderate Power



Bipolar Cells
Cells connected in series using bipolar elements.

High Power



Hybrid Bipolar Cells
Cells with multiple internal parallel connections that are connected in series using bipolar elements.

Performance requirements may be met by selecting the battery configuration most suited to the application.

Munitions Batteries

Design Innovations

State-of-the-art batteries support next generation electronic fuzing in projectile munitions

Advanced Power Source for Medium and Large Caliber Projectiles

G3207A1 - Cell

1S2P Internal Electrode Structure

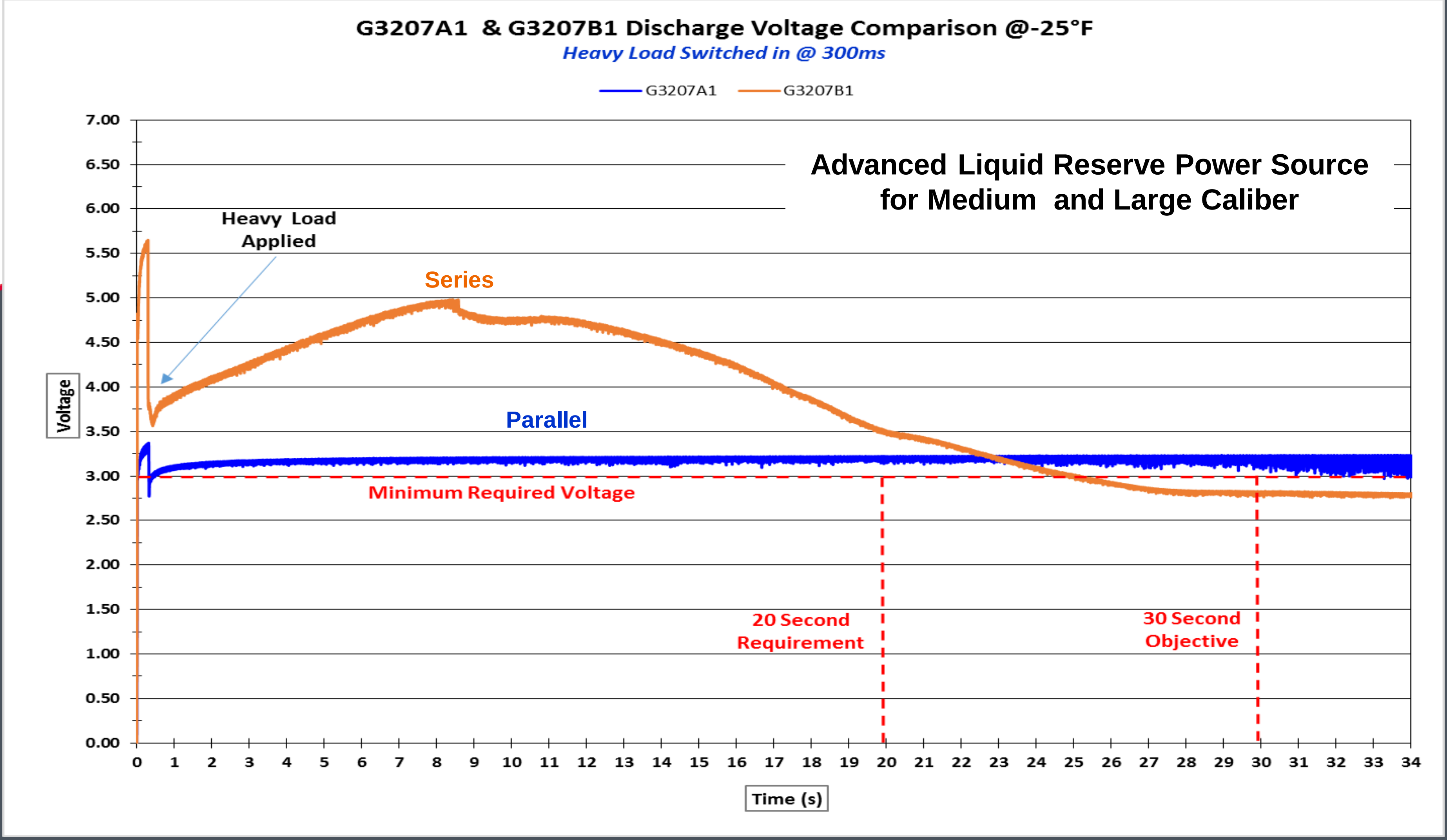
G3207B1 - Battery

2S1P Internal Electrode Structure

Power Source Size
∅0.450" Max X 0.395" Max Length
(Not including terminal pin)

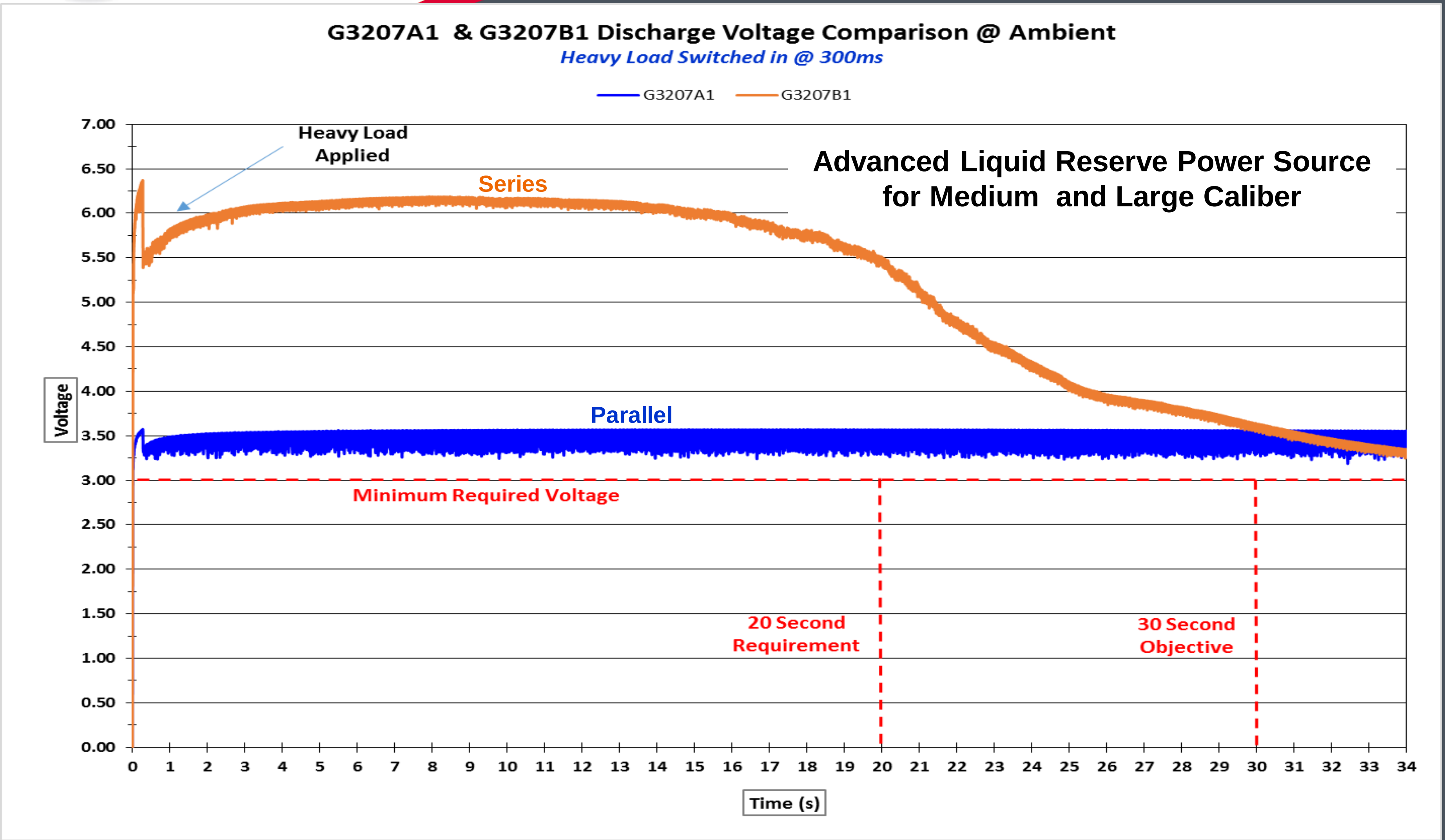
Innovative design allows for parallel or series electrode configurations in same size format. Power source can be configured to meet customers power and energy needs.

EAS – Munitions



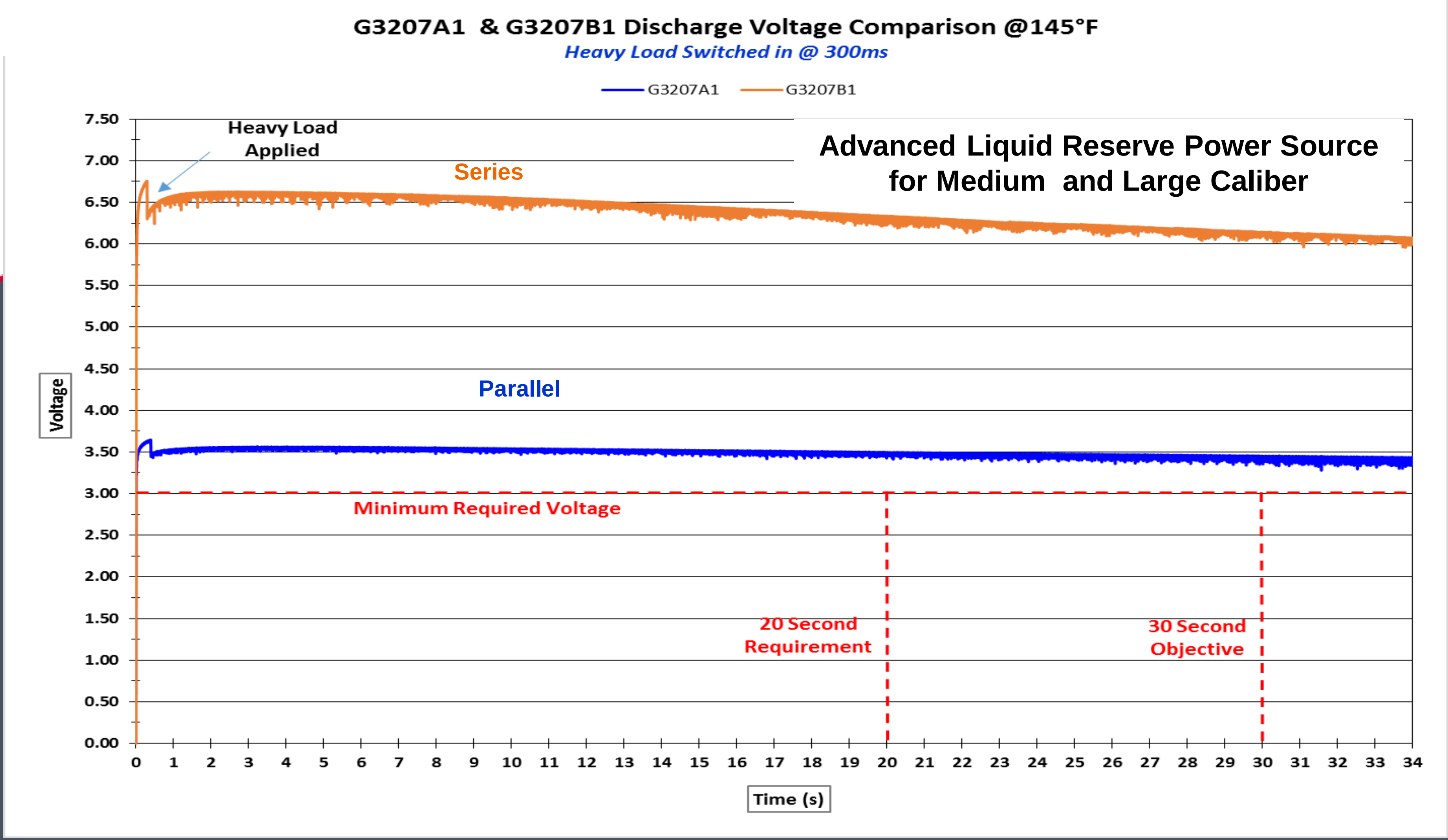
The series configuration provided higher voltage but shorter runtime under identical loading at the worse-case cold temperature extreme.

EAS – Munitions



The series configuration provided higher voltage but shorter runtime under identical loading at room temp ambient.

EAS – Munitions



The series configuration provided higher voltage but shorter runtime under identical loading at the worse-case high temperature extreme.

Munitions Batteries

Design Innovations

State-of-the-art batteries support next generation electronic fuzing in projectile munitions

Advanced Power Source for Next Gen Extended Range Projectiles

G3220A1 - Battery

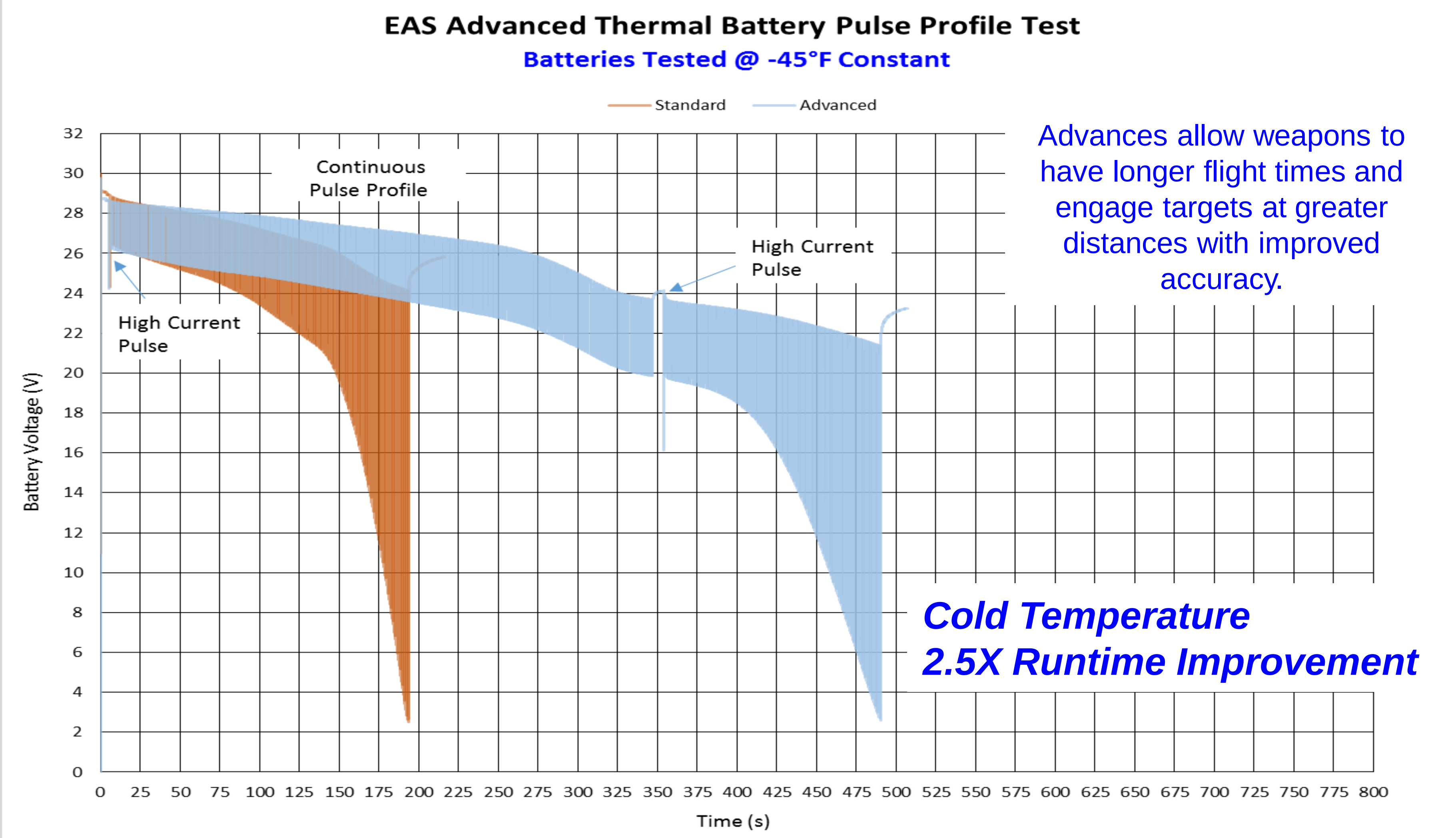
Power Source Size
∅1.50” Max X 3.00” Max Length
(Not including terminal pins)

Thermal Battery Innovations for Extended Runtime

- High Quality Electrode Materials
- State-of-the-Art Electrochemistries
- Advanced Mechanical Designs
  - Designed for Ballistic Launch Survivability
  - Designed for Optimal Thermal Management
- State-of-the-Art Insulation Materials
- Automated Production
  - High Rate Production
  - Consistent Build Quality
  - Repeatable Performance

Extended range capability in efficient battery size.

EAS – Munitions

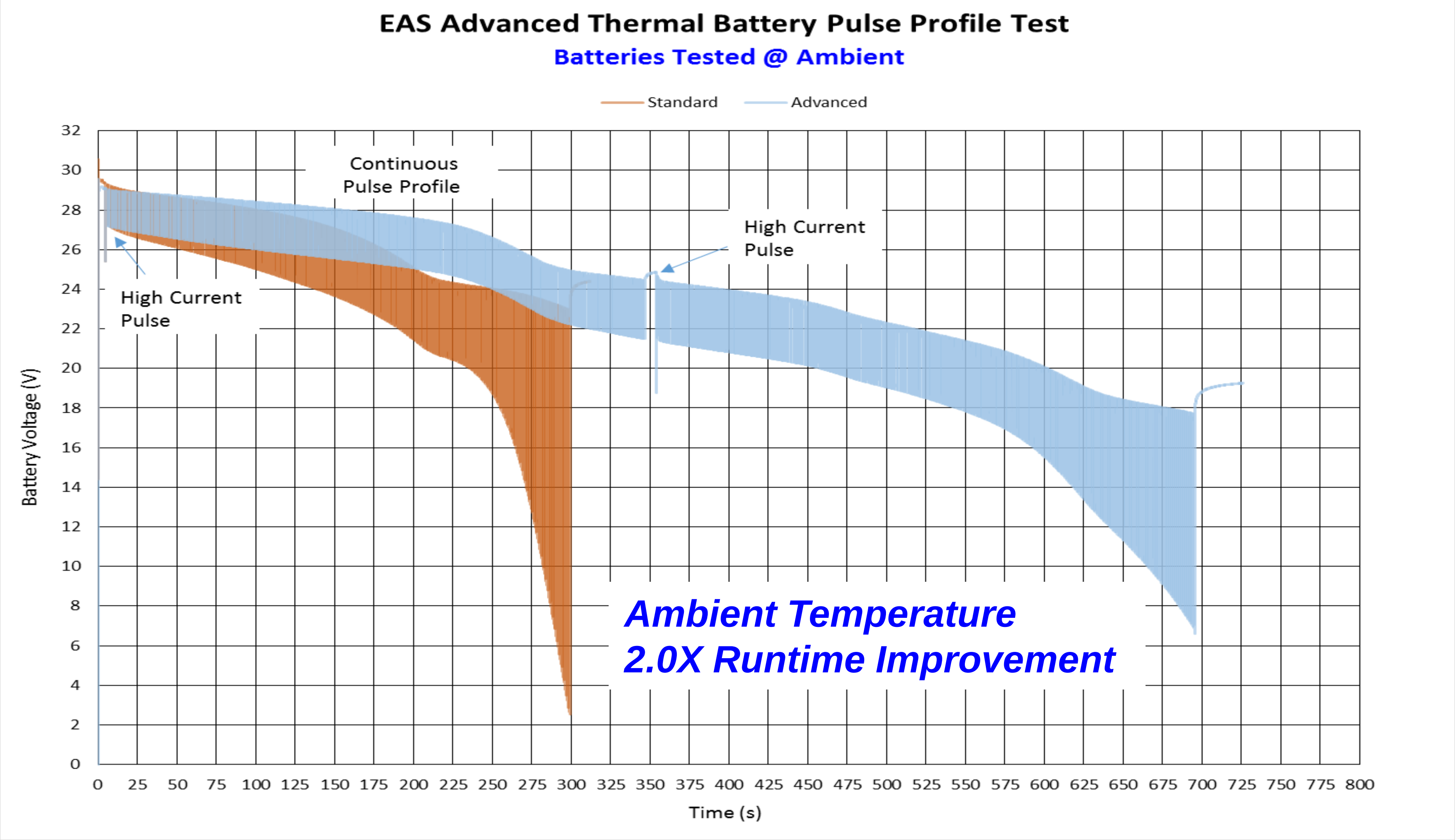


Advances allow weapons to have longer flight times and engage targets at greater distances with improved accuracy.

Cold Temperature
2.5X Runtime Improvement

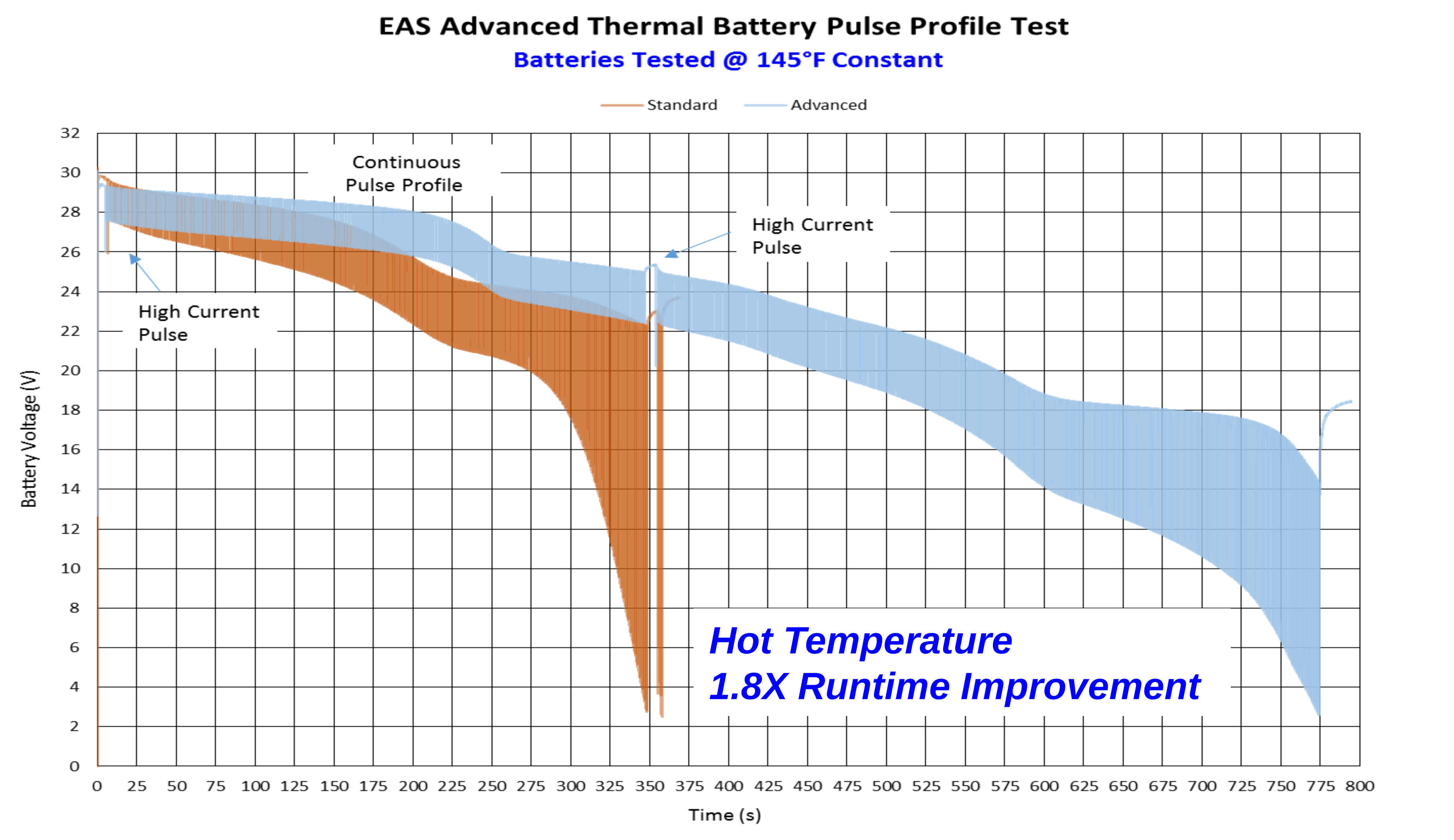
EAS's use of advanced materials, superior electrochemistry, and state-of-the art design resulted in 2.5X runtime improvement at cold temperature extreme.

EAS – Munitions



EAS's use of advanced materials, superior electrochemistry, and state-of-the art design resulted in 2.0X runtime improvement at ambient temperature.

EAS – Munitions



EAS's use of advanced materials, superior electrochemistry, and state-of-the art design resulted in 1.8X runtime improvement at hot temperature extreme.

Ambient Temperature Batteries

Selected Cells







	Sub-munitions	30 mm	40 mm	25 mm	40 mm	Munitions	Artillery
Device Number	G3168B1	G3201B1	G3198B1	G3165D1	G3207A1	G2666B1	G3147A1
Electrochemistry	Li/SO_2Cl_2	$Li/SOCl_2$	$Li/SOCl_2$	$Li/SOCl_2$	$Li/SOCl_2$	$Li/SOCl_2$	$Li/SOCl_2$
Size (in)	Φ.220 x .215	Φ.275 x .325	Φ.319 x .359	Φ.350 x .435	Φ.450 x .395	Φ.500 x .840	Φ.500 x .840
Voltage (V)	2.5 - 4.25	2.0 - 3.8	2.0 - 3.8	2.0 - 3.8	2.0 - 3.8	2.5 - 3.6	2.5 - 3.6
Current (mA)	0.250	20	30	30	50	0.5	0.5
Activation Time(s)	60.0	0.025	0.050	0.050	0.050	0.5	0.8
Run Time (s)	10 days	>30	>30	30	30	10 days	15 days
Capacity (mAh)	2.0	1.5	3.13	3.4	5.2	230	280
Weight (gm)	0.6	.875	1.25	2.0	2.0	5.1	6.2
Acceleration (G)	25,000.	100,000.	100,000.	70,000.	25,000.	7,000.	30,000.
Spin (RPS)	350	1,000.	2,100.	2,100.	300.	Low	500
Activation App.	Stab	Setback	Stab	Setback	Stab/Primer	Stab/Primer	Stab/Primer
Activation Acc. (G)	N/A	50,000.	N/A	8,000.	N/A	N/A	N/A
Applications	Self-Destruct Fuzing	30 mm Projectile Munitions	40 mm Air-bursting Non-Lethal Munitions	20 mm Projectile Fuzing & 84mm Rockets	40 mm Grenade Munitions	Barrier Munitions	Artillery Fuzing & Air Delivered Bombs

EnerSys offers a wide range of state-of-the-art Reserve Lithium/Oxyhalide Cells for medium and large caliber projectile fuzing.

Ambient Temperature Batteries

Selected Batteries






	40 mm	120 mm	120 mm	155 mm	Air Delivered	Projectiles
Device Number	G3207B1	G3153A2	G3153B1	G3158B3	G3161A1	G3177A1
Electrochemistry	$Li/SOCl_2$	$Li/SOCl_2$	$Li/SOCl_2$	$Li/SOCl_2$	$Li/SOCl_2$	$Li/SOCl_2$
Size (in)	Φ.450 x 0.395	Φ1.510 x 1.255	Φ.880 x 1.280	Φ1.500 x .670	Φ1.500 x .670	1.517 x 2.674
Voltage (V)	3.0 – 7.6	20.0 – 40.0	25.0 – 40.0	5.6 – 12.0	5.6 – 12.0	5.5 – 7.5
Current (mA)	50	750	500	350	350	36
Activation Time(s)	0.050	0.025	0.025	0.100	0.100	2.0
Run Time (s)	25	10	20	200	200	14 days
Capacity (mAh)	0.6	20.0	8.0	35	35	350
Weight (gm)	2.0	110.0	51.2	71.0	57.0	80.0
Acceleration (G)	25,000.	55,000.	55,000.	30,000.	30,000.	12,600.
Spin (RPS)	300	Low	Low	500.	Low	Low
Activation App.	Stab/Primer	Setback	Setback	Setback	Primer	Electric
Activation Acc. (G)	N/A	10,000.	10,000.	1,500.	N/A	N/A
Applications	40 mm Grenade Munitions	120 mm Tank Munitions, ES&A Fuzing	120 mm Tank Munitions, ES&A Fuzing	155 mm & 105 mm Artillery Fuzing	Electronic Fuzing, Projectiles, Bombs	Guidance, Data Hold Functions, Projectiles

EnerSys offers a wide range of state-of-the-art Reserve Lithium/Oxyhalide Batteries for medium and large caliber projectile fuzing.

Thermal Batteries

Selected Batteries






	Air Delivered	Artillery	Artillery	Mortar	Missile	105 mm
Device Number	G3190B2	G3197A3	G3200A1	G3202A1	G3206A1	G3208A1
Electrochemistry	$LiSi/FeS_2$	LiSi/FeS2	$LiSi/FeS_2$	$LiSi/FeS_2$	$LiSi/FeS_2$	$LiSi/FeS_2$
Size (in)	Φ1.50 x 2.380	Φ2.00 x 2.70	Φ1.515 x 1.905	Φ1.00 x 1.436	3.00 x 3.50	Φ1.10 x 2.85
Voltage (V)	22.0 - 32.0	23.8 - 34.0	5.0 – 8.4	11.0 – 23.0	24.0 – 35.0	18.0 - 32.0
Current (mA)	700	5,000.	750	11 W	800	11 W
Activation Time(s)	0.500	0.500	0.500	0.500	1.0	0.250
Run Time (s)	200	150	200	65.5	1,050.	55
Capacity (mAh)	39	412	39	20	730	64
Weight (gm)	250.0	463.0	190	80.0	1,360.0	198.0
Acceleration (G)	30,000.	15,000.	30,000.	11,000.	50.	25,000.
Spin (RPS)	Low	30	366.	50	Low	300
Activation App.	Electric	Electric	Setback	Electric	Electric	Setback
Activation Acc. (G)	N/A	N/A	2,000.	N/A	N/A	2,000.
Applications	Air Delivered Weapons	155 mm Artillery Fuzing	155 mm Artillery Fuzing	Electronic Fuzing, Projectiles, Bombs	Missile Electronics	105 mm Artillery Fuzing

EnerSys offers machine produced Reserve Batteries for high volume applications such as medium and large caliber projectile fuzing.

Munitions Batteries

Summary

- Several innovations were presented in the areas of electrochemistry and battery design that provide enhanced performance and capability for next generation electronic fuzing.
- Selected cells and batteries offering enhanced performance were discussed.
- EnerSys is a $3.0 billion/year American company with munitions battery manufacturing facilities located in Horsham, Pennsylvania and Tampa, Florida.
- EAS has all of the physical assets and facilities required to: design, develop, manufacture, test, and analyze lithium batteries.
- Thank you for your attention.

EnerSys provides high energy density "lithium/oxyhalide batteries" and high power density "thermal batteries" as well as secondary "lithium ion batteries".

EXPAL

FMCW Proximity Technology with Advance EM Insensitive Features

62nd Annual Fuze Conference

Fuzing Innovations for Tomorrow's Weapons

May 13 – 15, 2019 | Buffalo, NY

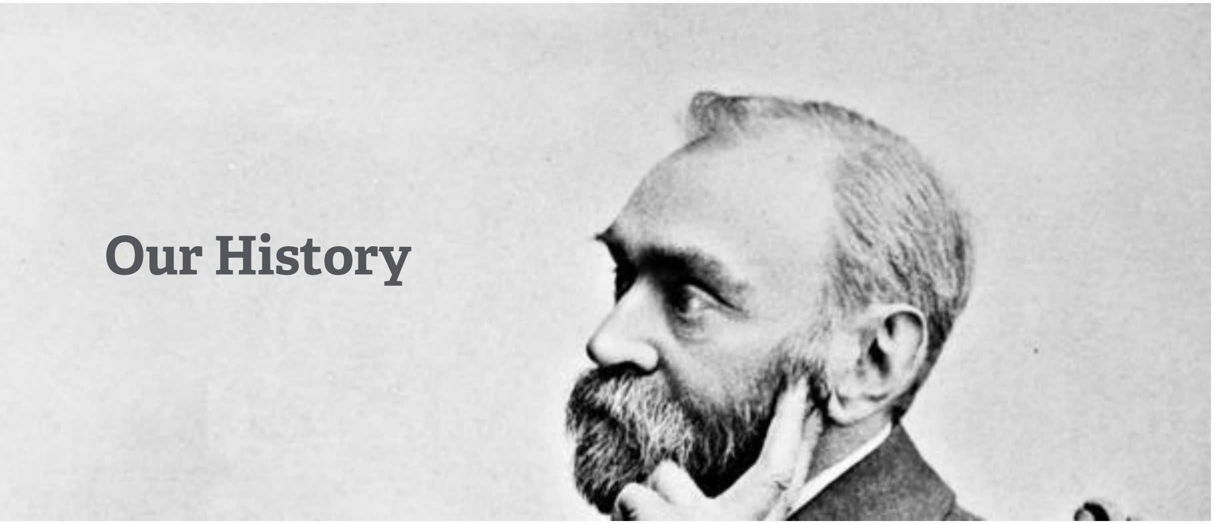
EXPAL Systems – Luis Abad, Product Manager

Content

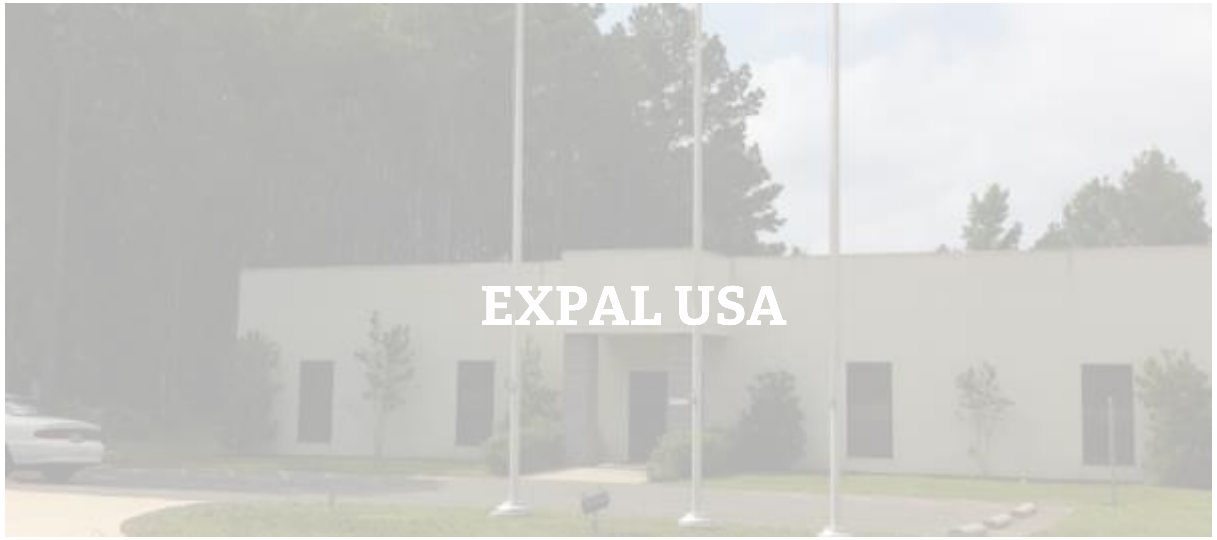
- A Story of frustration and success
  - Key Elements of Frustration
  - From Despair to Success
- Testing EM Immunity
  - Land Testing
  - AEGIS Proof Fire test
- Overall, Reliability
  - Production Key Facts
  - True Partners

ABOUT OUR GROUP


EXPAL


Our History


Global Solutions


EXPAL USA

EXPAL

PART OF A LEADING TECHNOLOGY COMPANY

MAXAM is a **global** leader; a company **technologically** specialized in the design, development, manufacturing and application of **energetic materials.**

Blasting and initiation systems for the mining, quarry and infrastructure industries

Terra Solutions

Cartridges and gunpowder for hunting and sporting use

Outdoors

Products and services for **defence and security industry**

Defense

Key raw materials for **nitro chemical activity**

Chem

EXPAL

History

19th

20th

21st Century

Partnerships with Armed Forces with a **diversified offering**

Strong commitment to **R&D** and **strategic** industry partnerships

Worldwide presence consolidation by extending our activities

First steps

1872 Alfred Nobel founded the SED ***Sociedad Española de la Dinamita, Privilegios A. Nobel***

National growth & consolidation

1911 First supply to the **Spanish Navy**

1979 Ammunition's **loading plant**, one of the **most important for NATO**

1986 Management of entire **life cycle of munitions**

International expansion

1990 Development of **high capacities** and **advanced technological elements**

Strategic partnership for **engineering services and systems' integration**

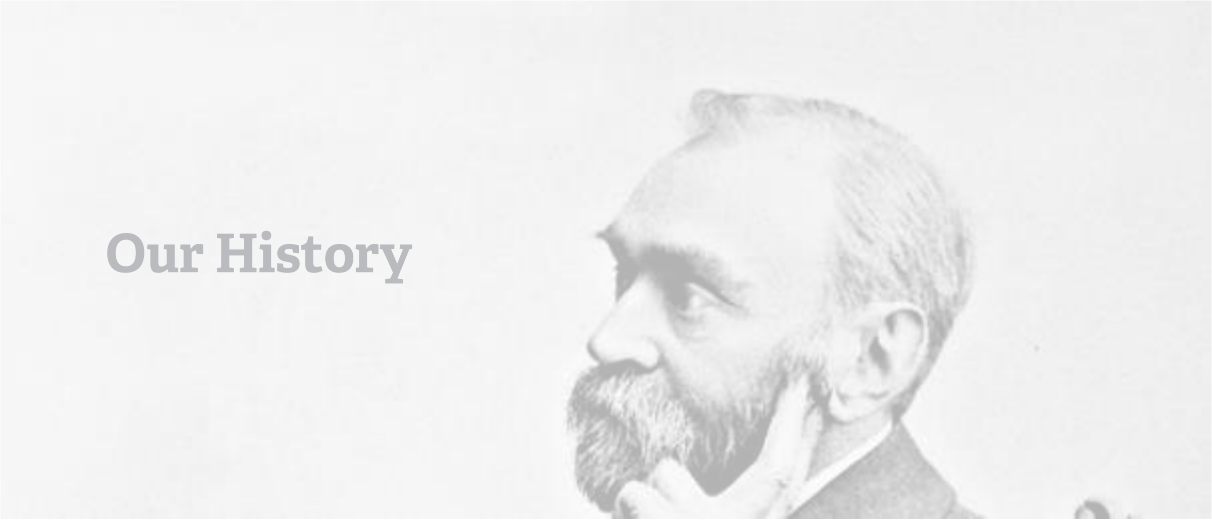
Consolidation as a global leader

Commercial activity in **5 continents**

3 Technology centers

11 Industrial sites:
US Establishment & R&D propellants plant


maxam
Beyond Performance


Our History


Global Solutions
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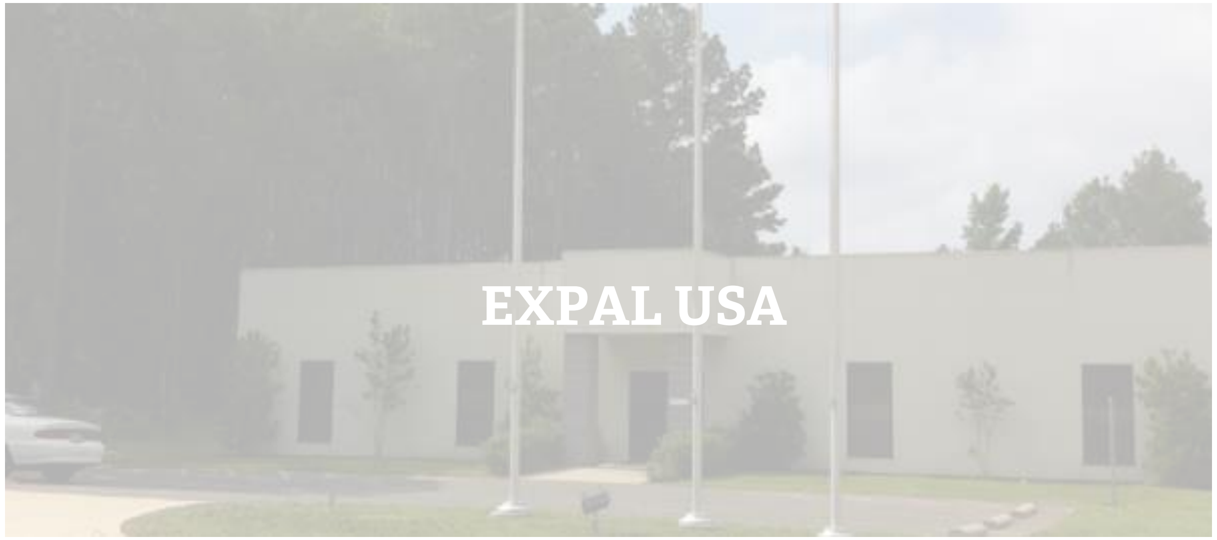
EXPAL USA

Allies of Armed Forces

- Solutions to + 25 Air Forces worldwide
- Complete air-to-ground warheads portfolio
- Compatible with most advanced precision guidance systems

- Leaders in mortar systems
- Complete ammunitions for Indirect fires support global solutions from 60mm to 155mm

- + 100 years providing naval solutions
- Vertical integration of key components

Fuzing Solutions for Every Scenario

- Fuzing since **1940**
- Presence in **+45 countries**
- **+500,000 units/year** manufacture (60mm up)
- **STANAG Qualified** solutions for Mortar Grenades and Field Artillery
- **In-house production** of key components (energetics and electronics)

Fuzing Solutions for Every Scenario

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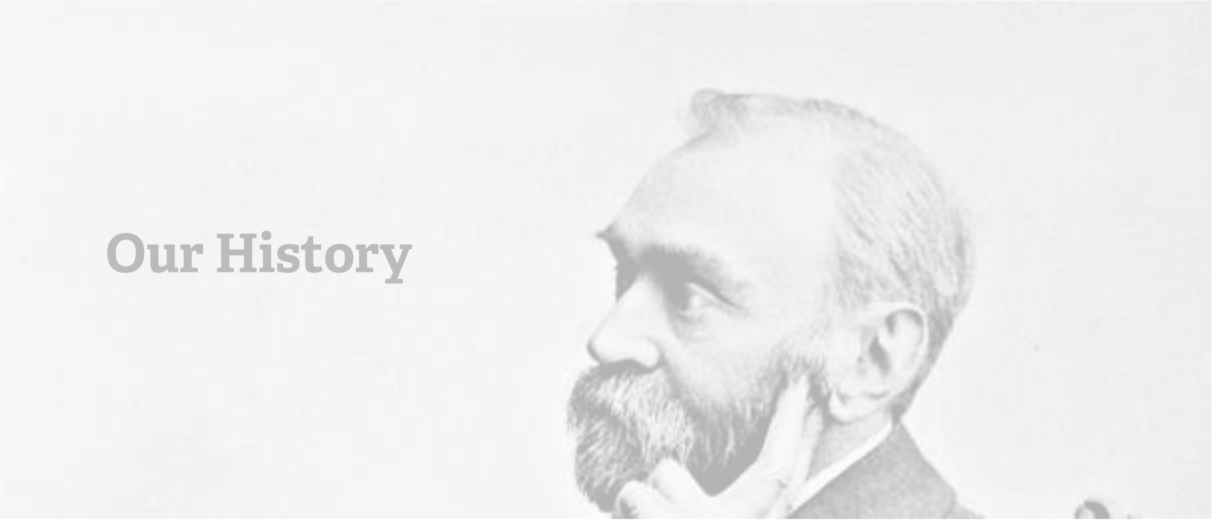
- Presence in **+45 countries**
- **+500,000 units/year** manufacture (60mm up)
- **STANAG Qualified** solutions for Mortar Grenades and Field Artillery
- **In-house production** of key components (energetics and electronics)

- **Unique competences** as complete rounds manufacturer (availability and know-how)
- **Complete Portfolio** for large calibre ammunition (+60mm)
- **U.S design** based mechanical fuzes **(M739, MTM/MTSQ)**

- Leading **electronic & proximity fuze technology**


MAXAM
Beyond Performance


Our History


Global Solutions


EXPAL USA

Directly Supporting the US Armed Forces

- **2 Industrial Sites:**
  - **Texarkana, TX**
  - **Minden, LA**

Texarcana

- 200 acres site, **Currently** Ammo LAP, demilitarization, recycling and recovery of munitions and components.

Capabilities for bringing in EXPAL's expertise in other ammo solutions (Fuzes M739, MTM/MTSQ)

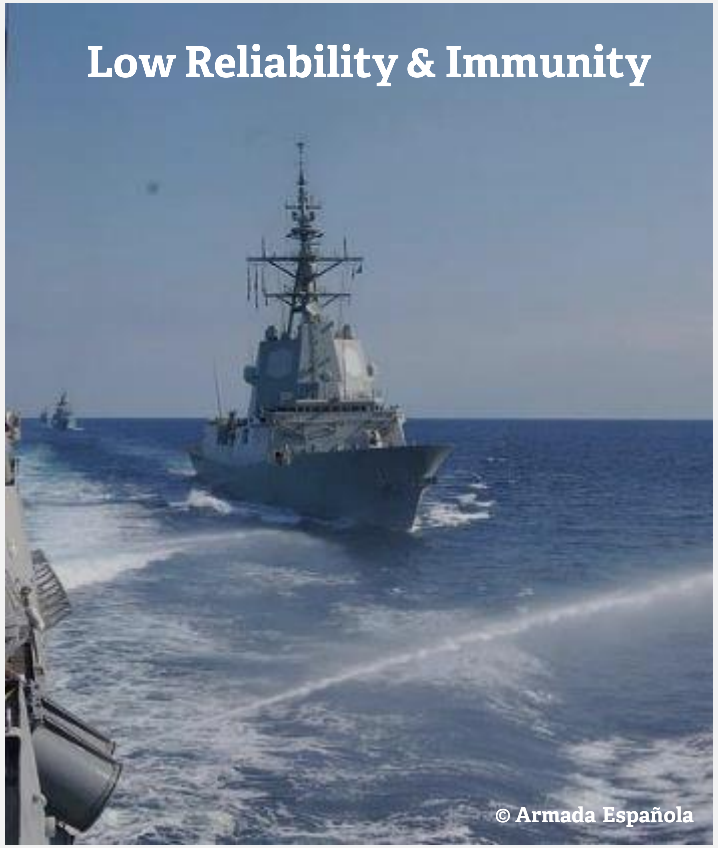
Minden

- 100 acres flexible explosive processing plant (incl. twin-screw extruder) with analysis lab

- DCMA site safety survey approved
- BATF&E Type **2X permits**
- Louisiana explosive licenses

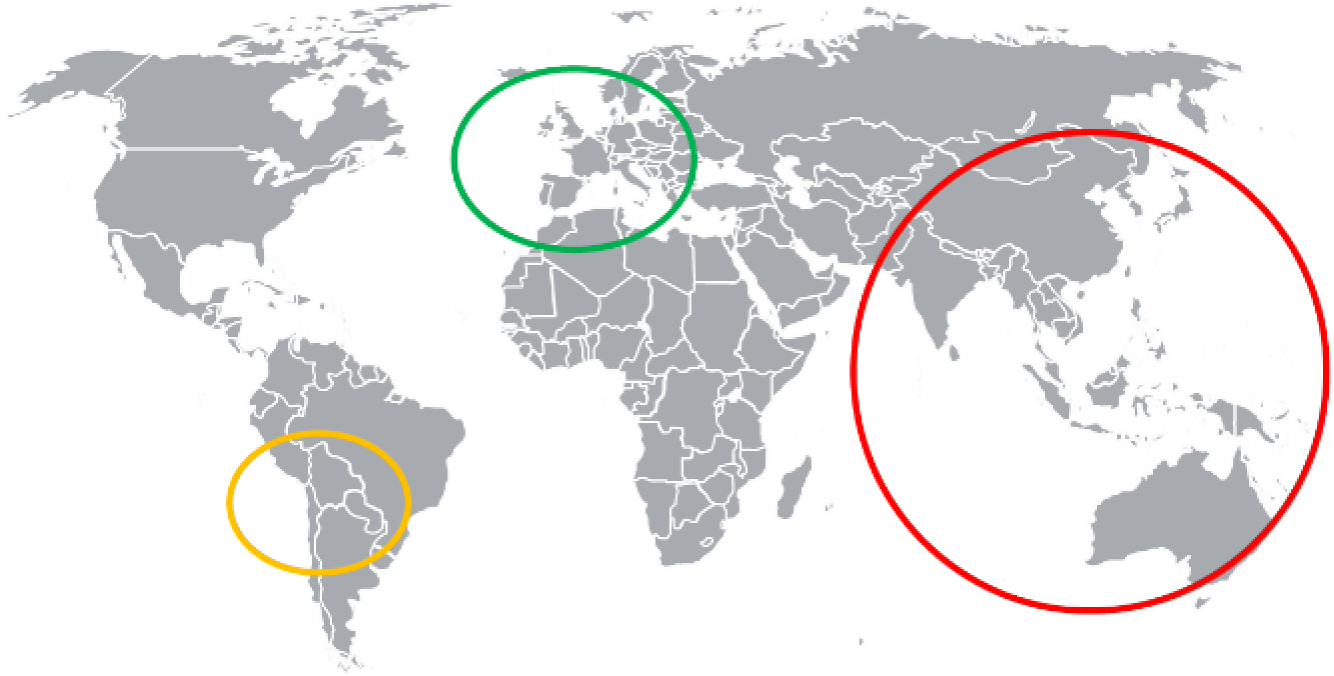
A Story of Frustration and Success

Key Elements of Frustration



- Current standard ordnance solutions not at the same level than Combat Systems
  - Low Reliability **(<90%)**
  - Dramatically affected by EM Environments
  - Potential Safety Issues **(prematures)**
- Proximity detection and processing based in 80's available technologies
  - Complete Obsolescence **(transistors/oscillators/mixers)**
  - Big Supply Chain Problems and Manufacture unproductiveness **(Big Scrap)**
- **Suprisingly, a very common worldwide non recognized situation**

Key Elements of Frustration



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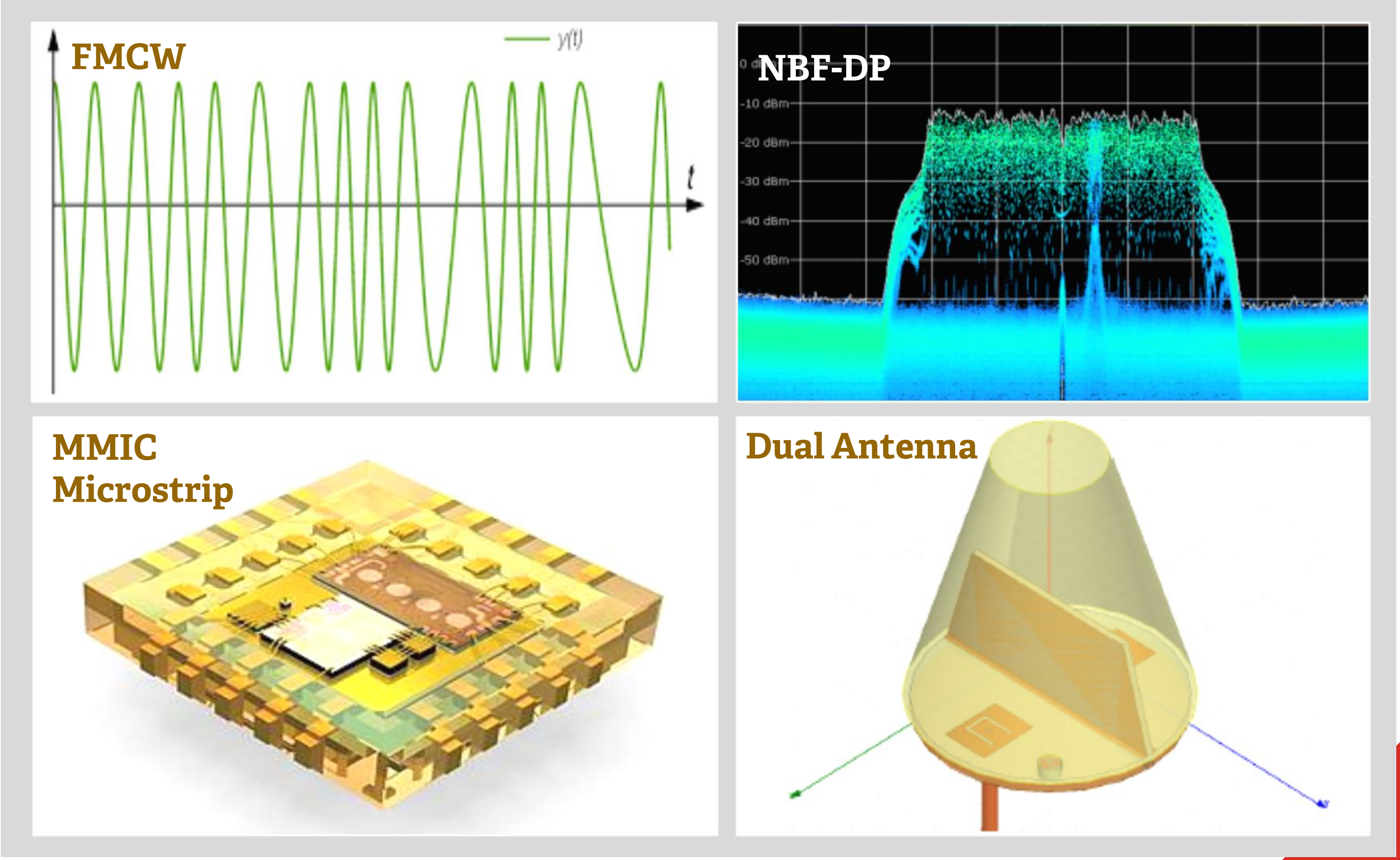
- **Suprisingly, a very common worldwide non recognized situation**

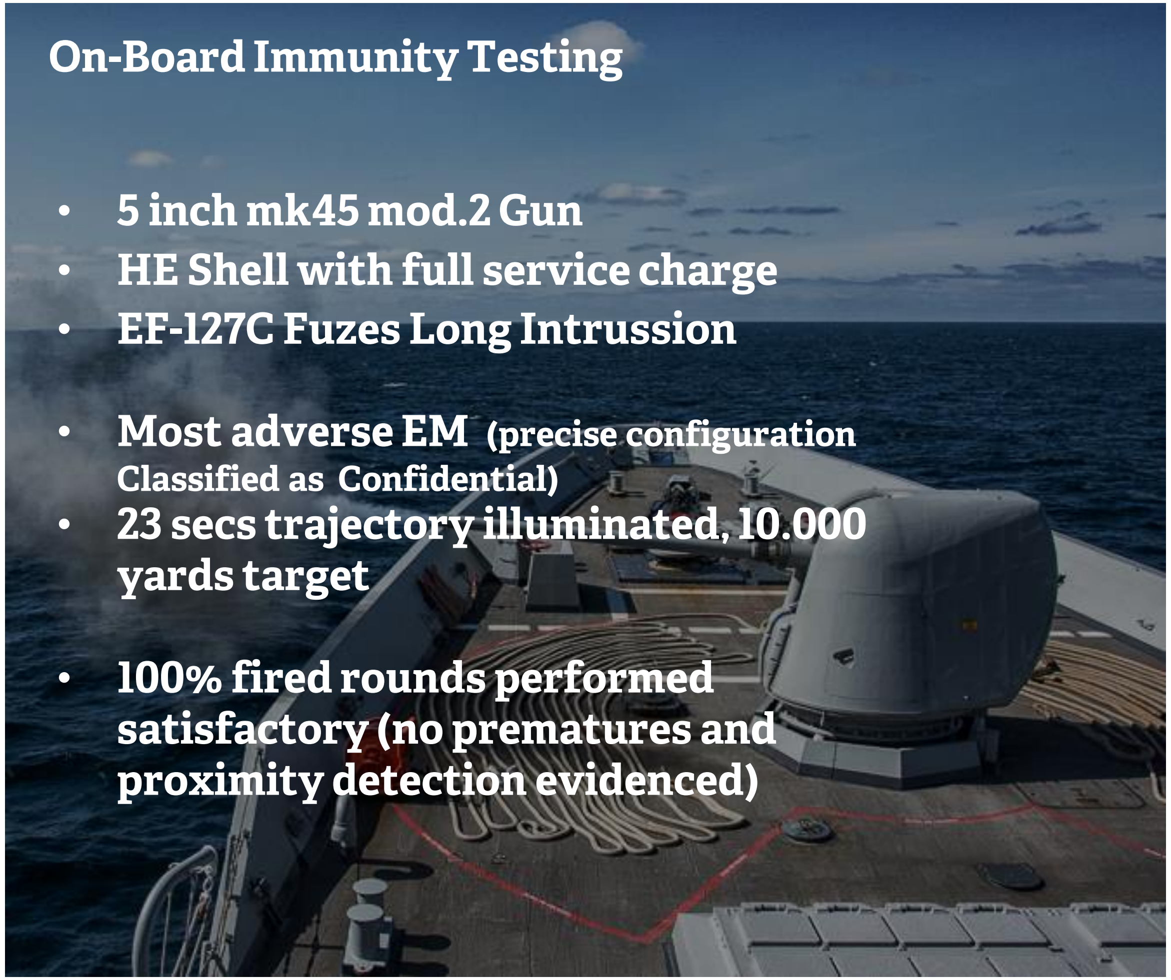
From Despair To success

- Development Program started in **2009** sponsored by the Spanish Navy.
- Several Stages, concluding proximity in **2015**,
- Operative Fuzes in service since 2016.
- Still, 76 and 127mm subjected to improvements until **2017**, wrapping up the project.



Testing

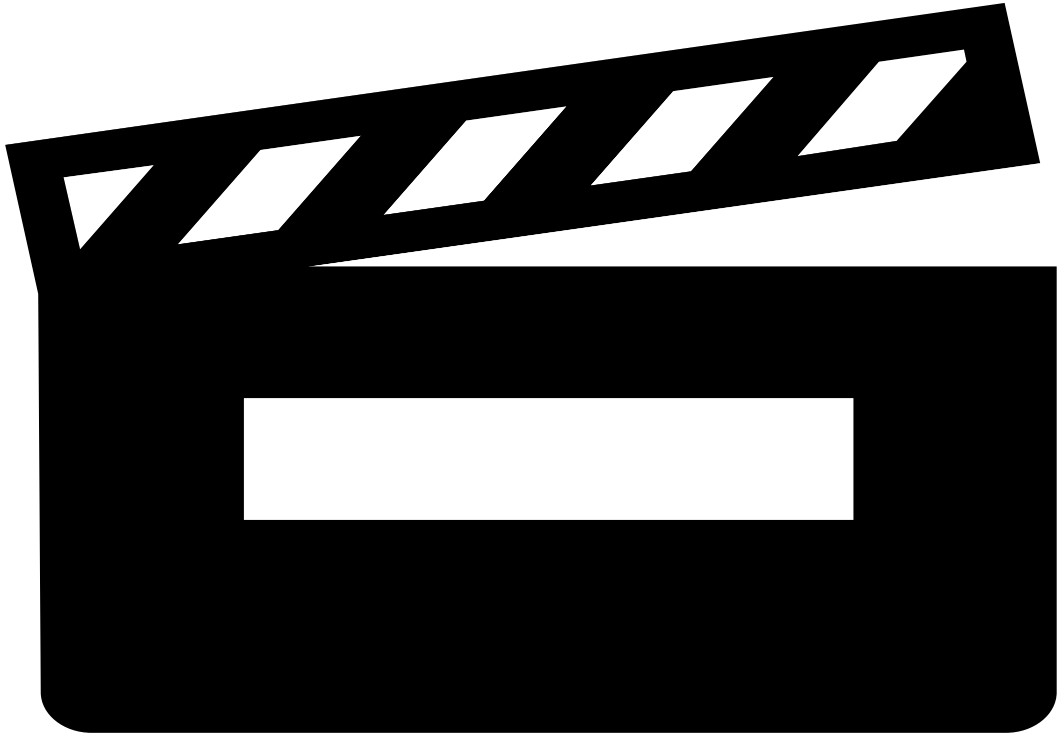
Testing EM Immunity



On-Board Immunity Testing

- 5 inch mk45 mod.2 Gun
- HE Shell with full service charge
- EF-127C Fuzes Long Intrussion
- Most adverse EM (precise configuration Classified as Confidential)
- 23 secs trajectory illuminated, 10.000 yards target
- 100% fired rounds performed satisfactory (no prematures and proximity detection evidenced)

Fire Testing



Overall, Reliability

PRODUCTION KEY FACTS

+10,000
76mm & 5" Fuzes put in service

5 countries
already trusting us

4 guns
Compatibility tested

~ 300
Fuzes tested

+95%
Reliability in Prox.Detec. (~98% combined)

0
Premature

A TRUE PARTNER

In constant R&D&i

- Improvements for present products profiting of everyday new techs.
- R&D's for Multi-option an Combat Sys. integration with Spanish Navy

Applying stable & reliable solutions

- In-house production & integration of key components
- Reliable mechanical solutions

Focused in customer needs

- Engineering answering to the Armed Forces needs
- Tailored solutions


Thank you

Guided Munitions for Aerial Gunnery; Increased Mission Effectiveness and Large Cost Savings

L. Schumacher[1] R. Barrett[2]

[1] PhD Student, University of Kansas

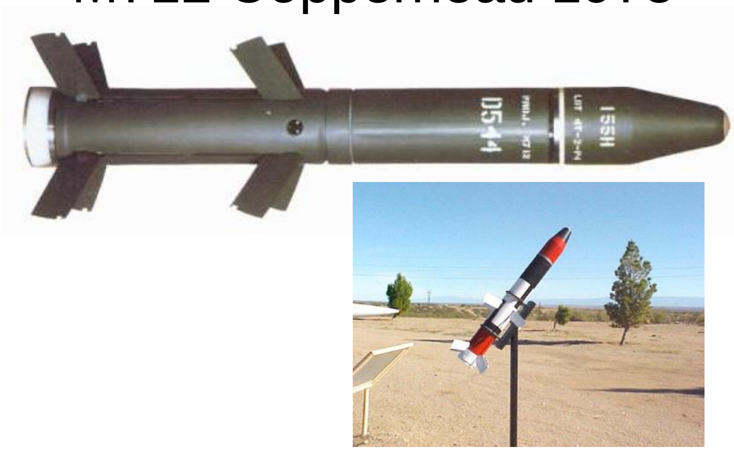
[2] Professor of Aerospace Engineering
Adaptive Aerostructures Laboratory Director

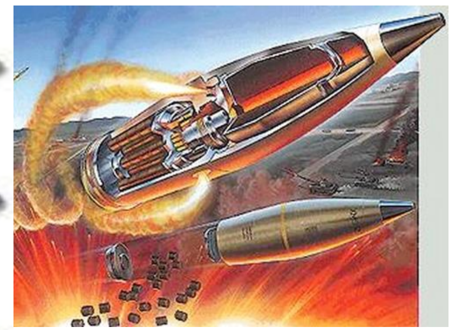
National Defense Industrial Association

62nd Annual Fuze Conference, 2019

- Introduction
  - Guided Hard Launch Munitions (GHLM)
- Concept of Operations
- Aerial Applications
  - F-15
  - FAC-130
  - F-35
- Future Work

M712 Copperhead 1975





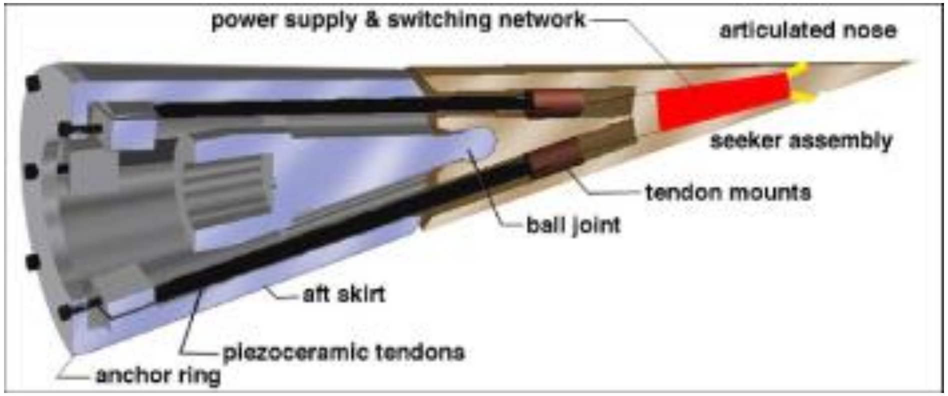
XM 982 Excalibur
& ERGM

Barrel-Launched Adaptive Munition (BLAM) Program 1995 - ’97

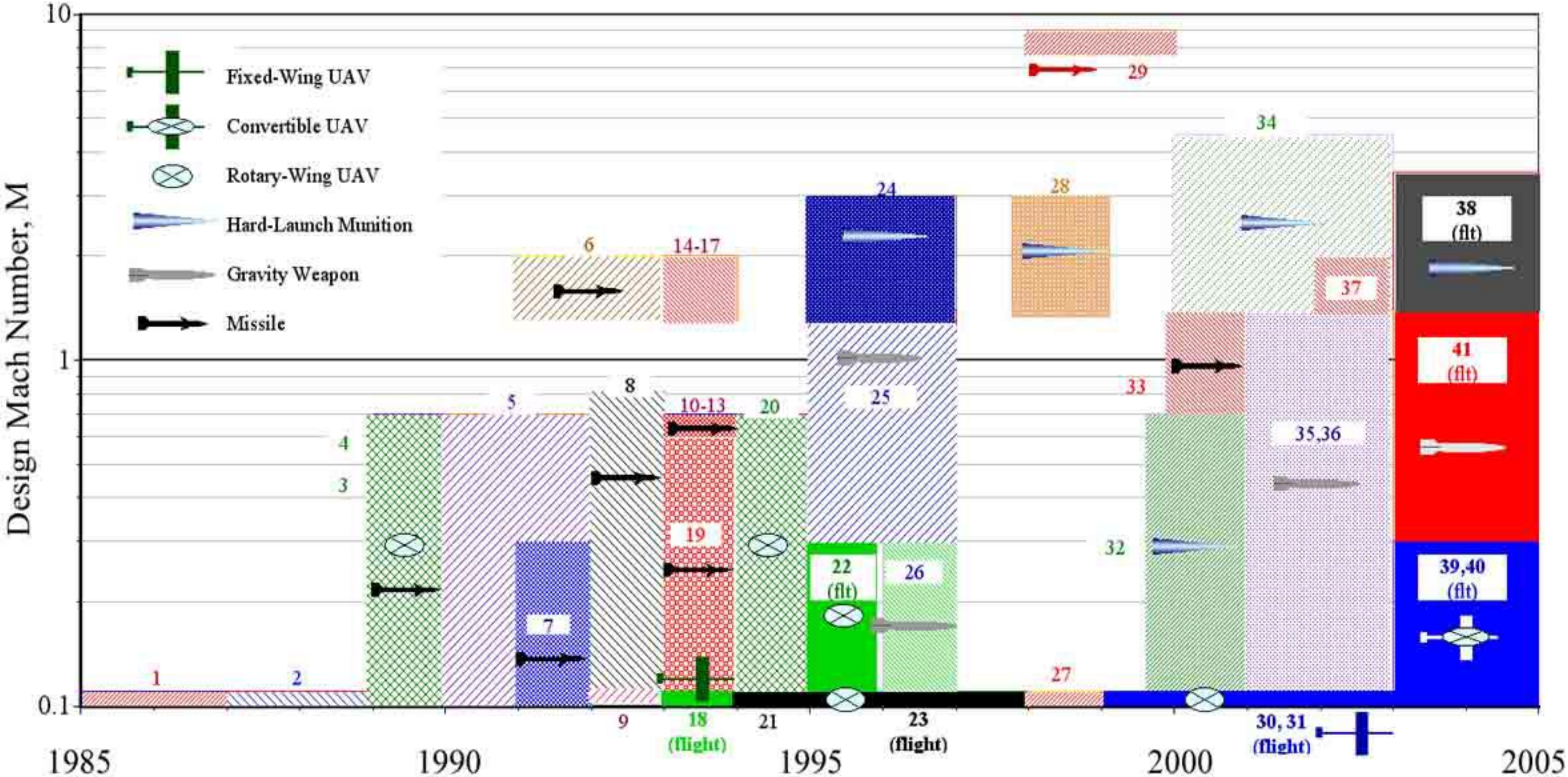
USAF/AFRL-MNAV

- Aerial Gunnery (20 - 105mm)
- Extend Range w/2g maneuver
- (Eglin AFB tests ‘97)

  (Mach 3.3 tests ‘96-’97)
- Increase hit probability
- Increase probability of a kill given a hit
- Reduce total gun system weight fraction



AAL: Building Adaptive Actuators for Hard-Launch Munitions since 1995

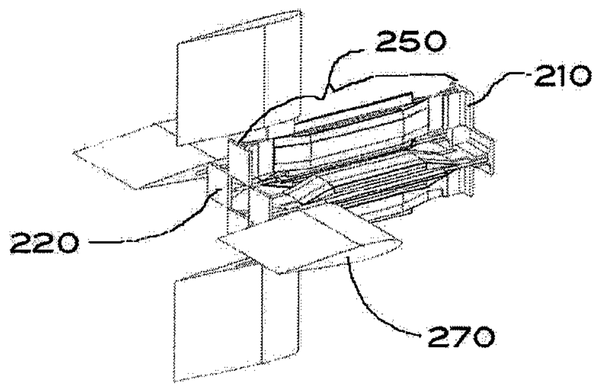


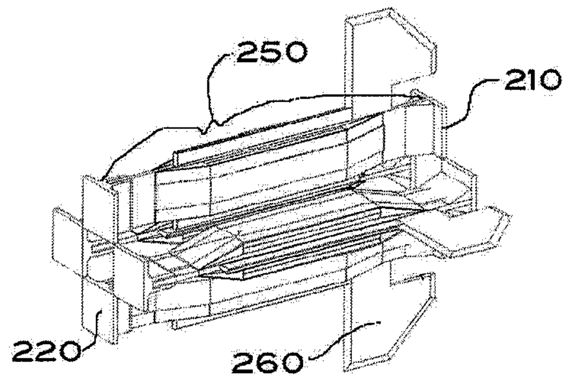
Historic Guided Hard-Launch Munitions

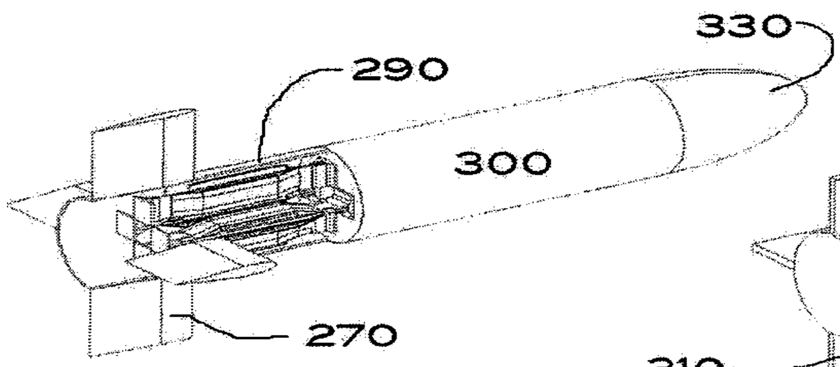
- Copperhead: 155mm, USA Armament Research
  - 1970's indirect fire against hardened targets
- Adaptive Guided Munitions Programs
  - Barrel Launched Adaptive Munition (BLAM), 1995, conical round, USAF Armament Directorate
  - Hypervelocity Interceptor Test Technology (HITT), 1998, USA Space and Missile Defense Command
  - Range-Extended Adaptive Munition (REAM), 1998, sniper round, derivative—SCREAM, USA Armament Research, Development, and Engineering Center
  - Light Fighter Lethality Adaptive Round (LFLAR), subsonic, USA Armament Research
- Extended Range Guided Munition (ERGM), Raytheon
  - Rocket Assisted Projectile (RAP), 5 in diameter, 13-54nmi (Cancelled)
- Extreme Accuracy Tasked Ordnance (EXACTO), DARPA
  - DARPA initiative, small caliber guided sniper round, live fire tests in 2015
- M982 Excalibur, Raytheon
  - 155mm GPS and inertial guided munition for close-support
- Multi-Azimuth Defense Fast Intercept Round Engagement System (MAD-FIRES), DARPA
  - DARPA initiative, medium caliber guided rounds

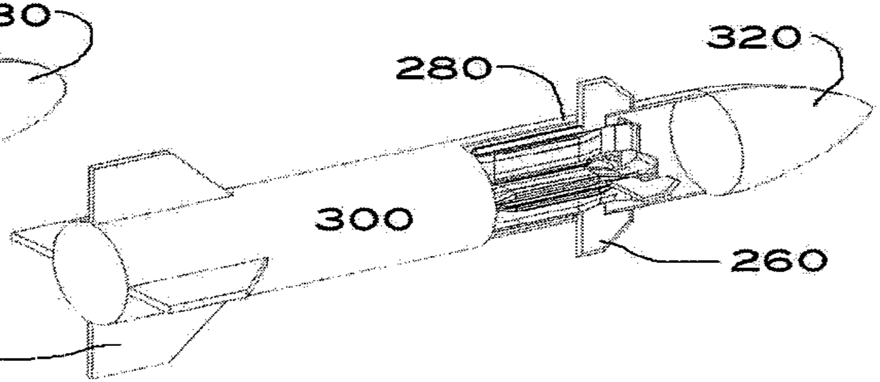
AAL: Issued patents & 2 decades of test data up to: Mach 11, 1kHz, 100,000g's

PBP-Class Hard-Launch Capable Full-Proportional Actuator FCS Units:

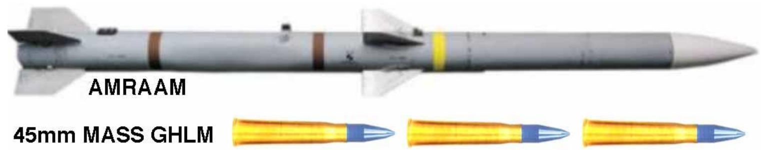




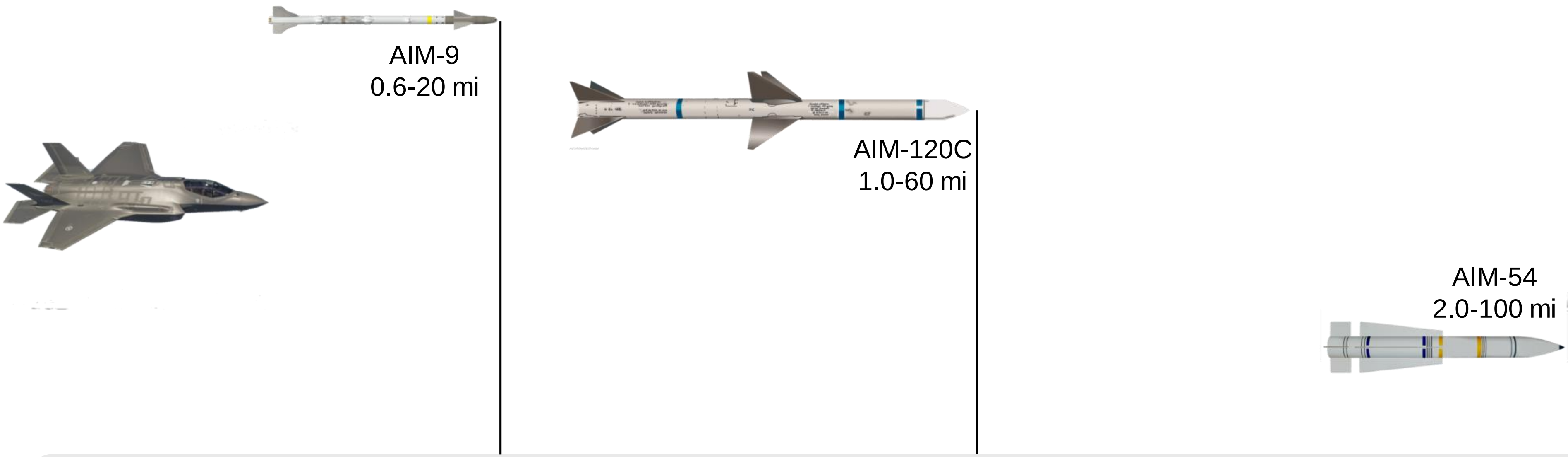




Application to Aerial Platforms: Retrofit



- ➢Increased Number of Targets
- ➢Expanded Engagement Range Envelope
- ➢Airframe Defense with Maneuver Overmatch
- ➢Decreased Cost per Kill



Guided Hard-Launch Munitions
0-100+ mi

- Reduced Observables (RF, IR & Acoustic)
- Increased Airframe Performance
    - Reduction in platform weight, wetted area, and total volume

[1]

[2]

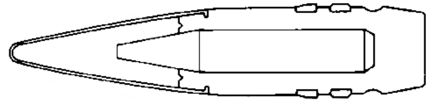
- Energy based analysis: interior and terminal ballistics
- 6 DOF ballistic model
- Simplified intercept in simulated atmosphere

$$\Phi_w(\omega) = \frac{2\sigma_w^2 L_w}{\pi V} \frac{\left(1 + \frac{8}{3} * \frac{2.678 L_w \omega}{V}\right)^2}{\left(1 + \left(\frac{2.678 L_w \omega}{V}\right)^2\right)^{\frac{11}{6}}}$$

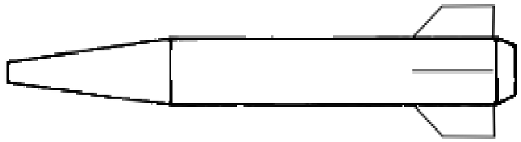
$$\frac{d\bar{V}}{dt} = -\frac{\rho V S C_D}{2m}\bar{V} + \frac{\rho S C_{L_\alpha}}{2m}\left(V^2\hat{x} - (\bar{V}\cdot\hat{x})\bar{V}\right) + \bar{g}$$

$$\frac{d\bar{h}}{dt} = \frac{\rho V S d^2 C_{l_p}}{2I_y}(\bar{h}\cdot\hat{x})\hat{x} + \frac{\rho V^2 S d \delta_F C_{l_\delta}}{2I_y}\hat{x} + \frac{\rho V S d C_{M_\alpha}}{2I_y}(\bar{V}\times\hat{x})$$

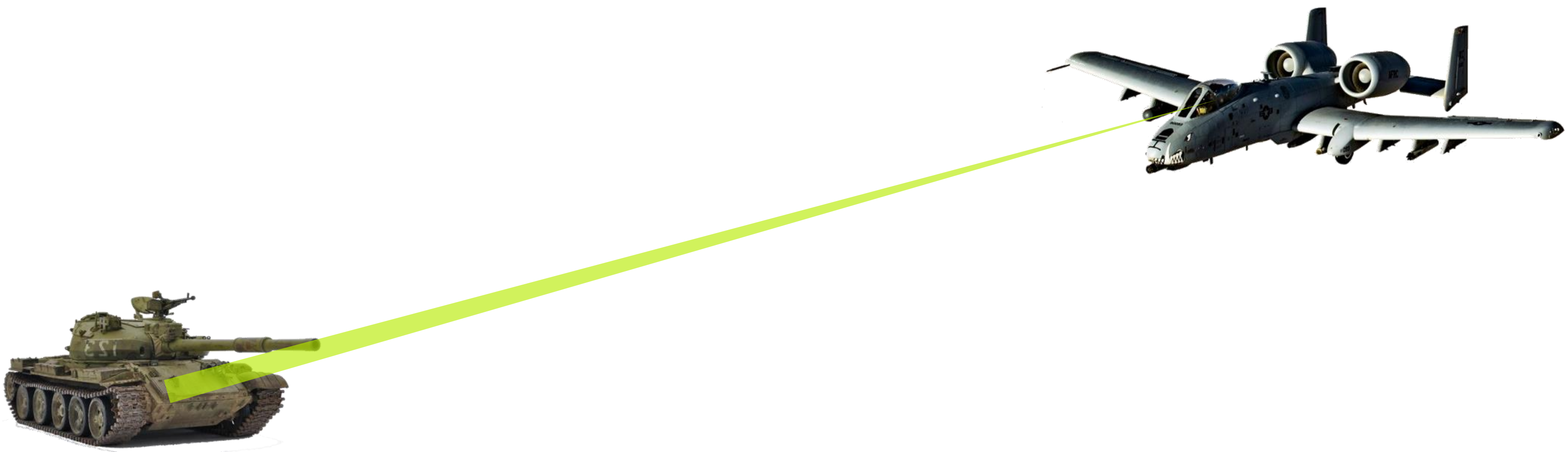
- Increase impact kinetic energy at Effective Range:
  - PGU-14 E_{impact}/E_{muzzle} ~ 51%



  - MASS GHLM E_{impact}/E_{muzzle} ~ 89%

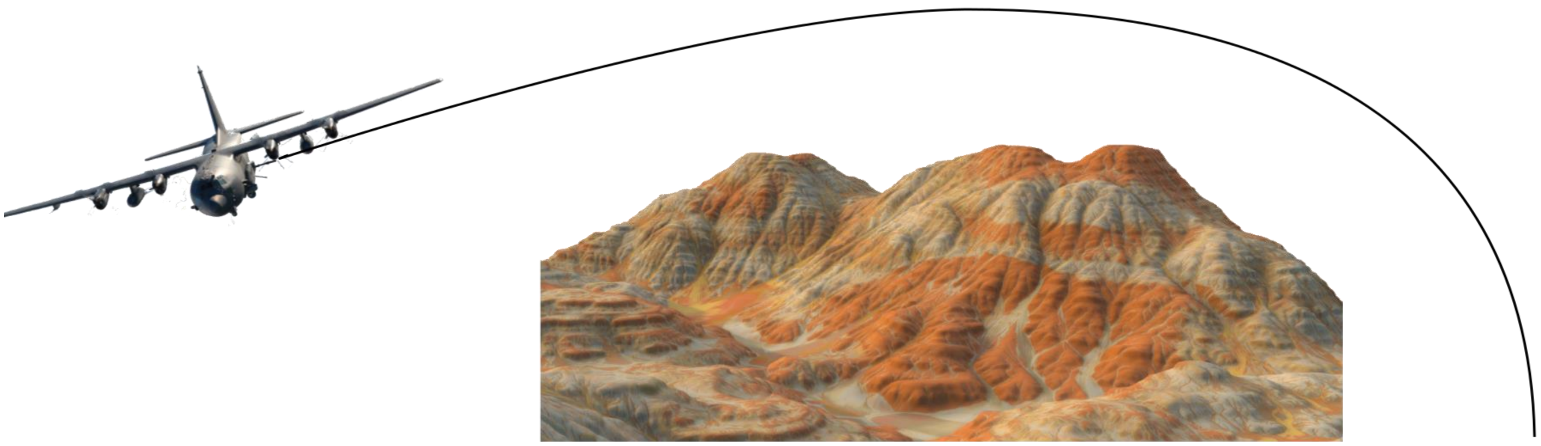


- MASS Guided Variants



Concept of Operations: Indirect Fire

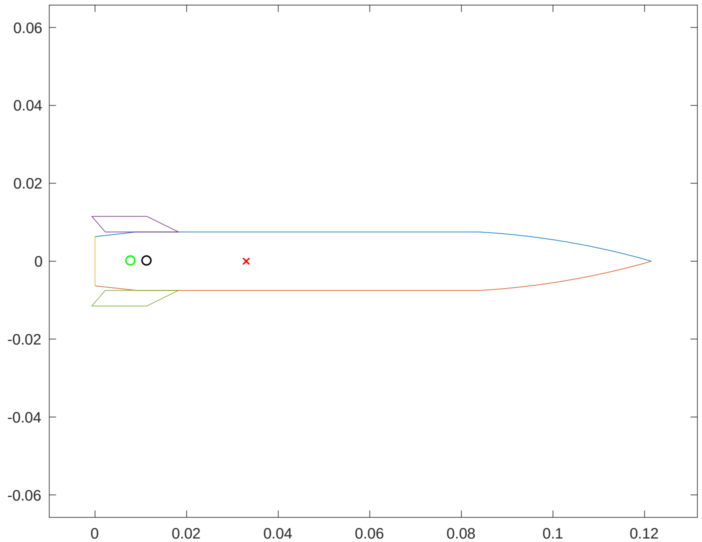
- MASS Guided Indirect Fire
  - Semi-ballistic path
  - Terminal Guidance

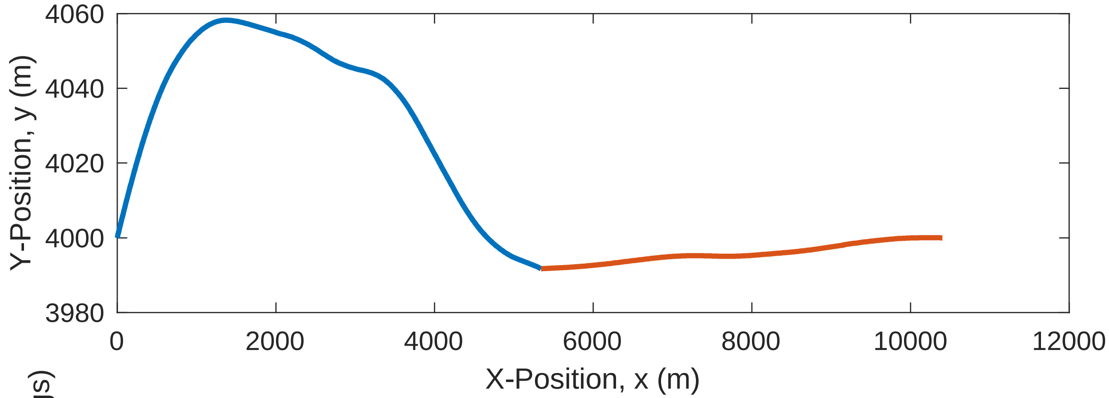


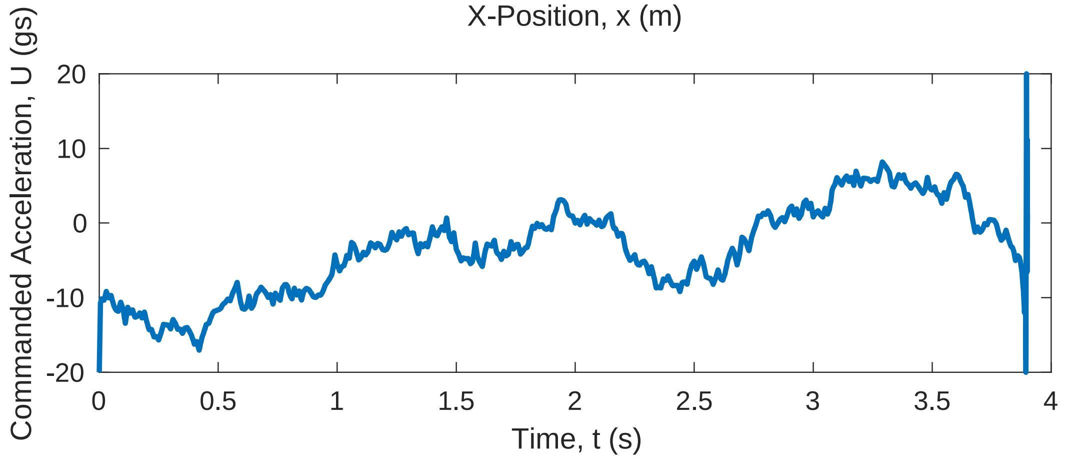
Concept of Operations: Defensive Overmatch

- MASS GHLM IR defense
  - Flying “flare”
- MASS GHLM RF defense
  - Kinetic kill
  - Proximity with debris field

- Maneuver Specification
- Simulated R-77 intercept



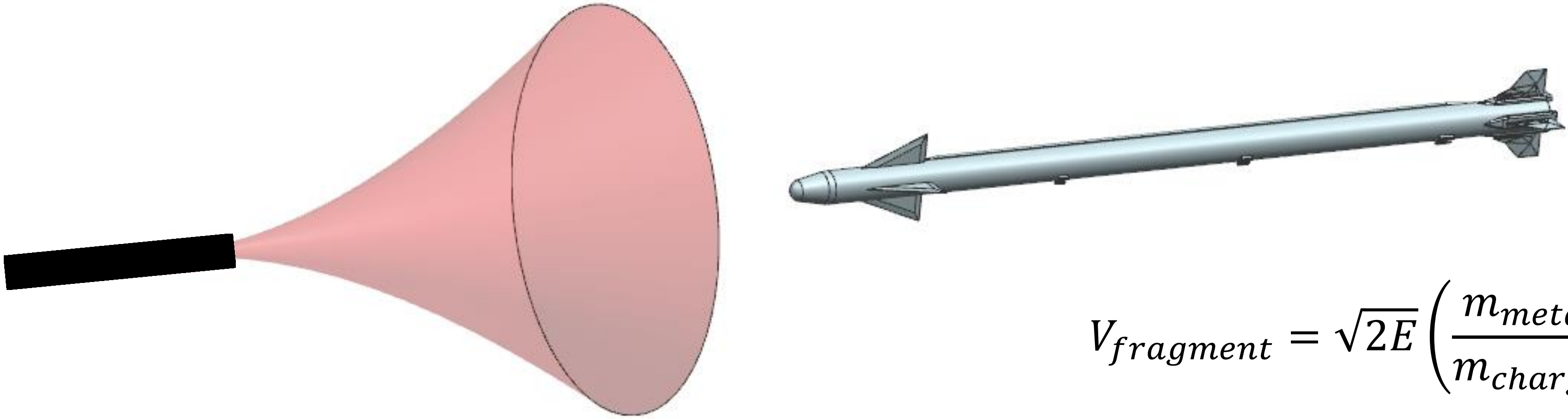




- P_k estimation
  - Cost/kill of MASS GHLM < conventional missile

- Miss radius estimation

$$N = \frac{\ln\left(1 - P_{k,desired}\right)}{\ln\left(1 - P_{k,projectile}\right)}$$



$$V_{fragment} = \sqrt{2E}\left(\frac{m_{metal}}{m_{charge}} + \frac{1}{2}\right)^{-\frac{1}{2}}$$

- Existing Loadout
  - 4 x AIM-9
  - 8 x AIM-120
  - 940 x 20mm
- M61 Vulcan retrofit

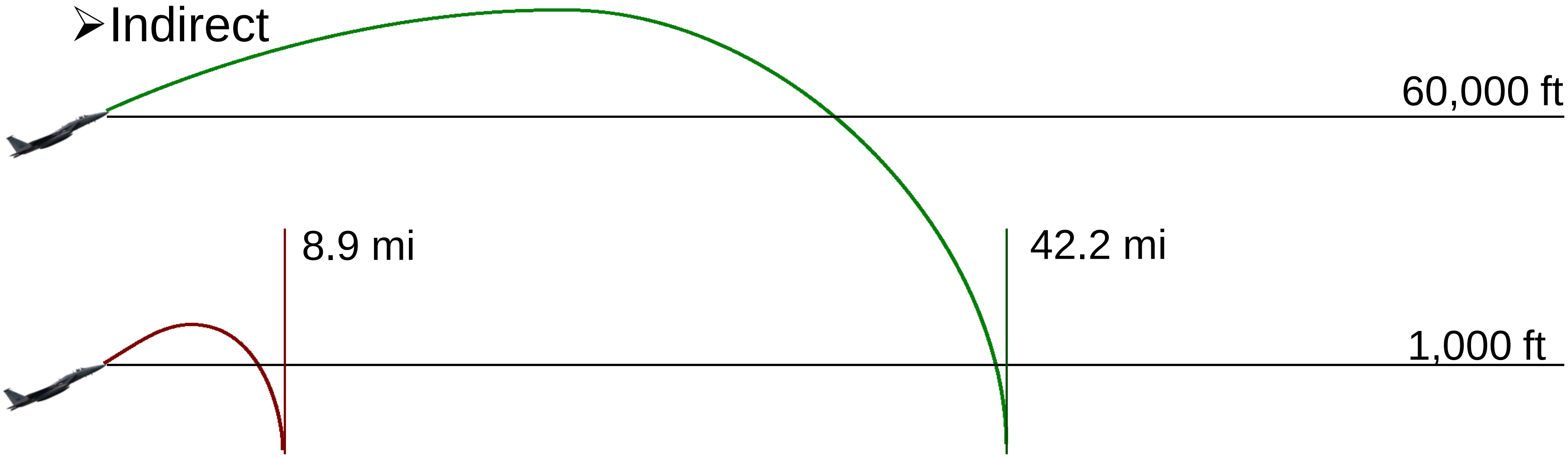
[4]

[5]

- Simulated retrofit PGU-28 series:
  - Direct fire near sea-level

	PGU-28 A/B	20mm MASS GHLM	% Change
Projectile Mass (kg)	0.11	0.11	~
Effective Range (mi)	1.28	1.90	+48%
Ballistic Coefficient (PGU reference form factor)	1.03	1.87	+81%

  - Indirect



- Existing Loadout AC-130U Spooky II
    - 1 x 25mm GAU-12/U
    - 1 x 40mm L/60 Bofors
    - 1 x 105mm M102

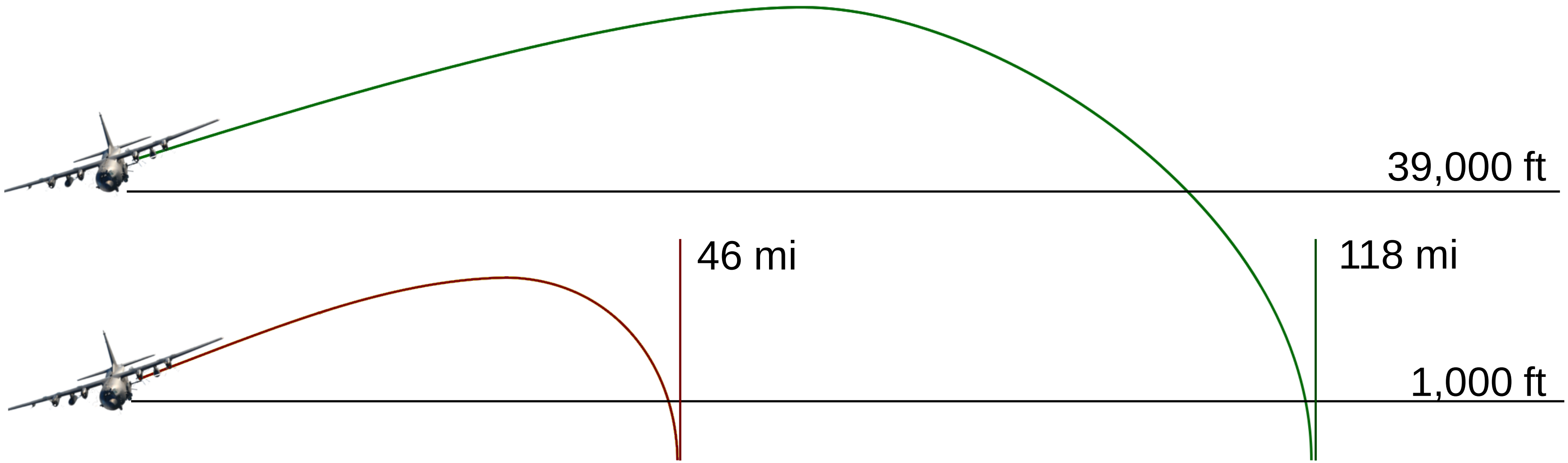
- M102 retrofit

[6]

- Simulated retrofit M1 series:
  - Direct fire near sea-level

	M1	105mm MASS GHLM	% Change
Projectile Mass (kg)	18	18	~
Kinetic Energy at Impact (kJ)	607	788	+30%
Ballistic Coefficient (M1 reference form factor)	2.34	3.81	+63%

  - Indirect



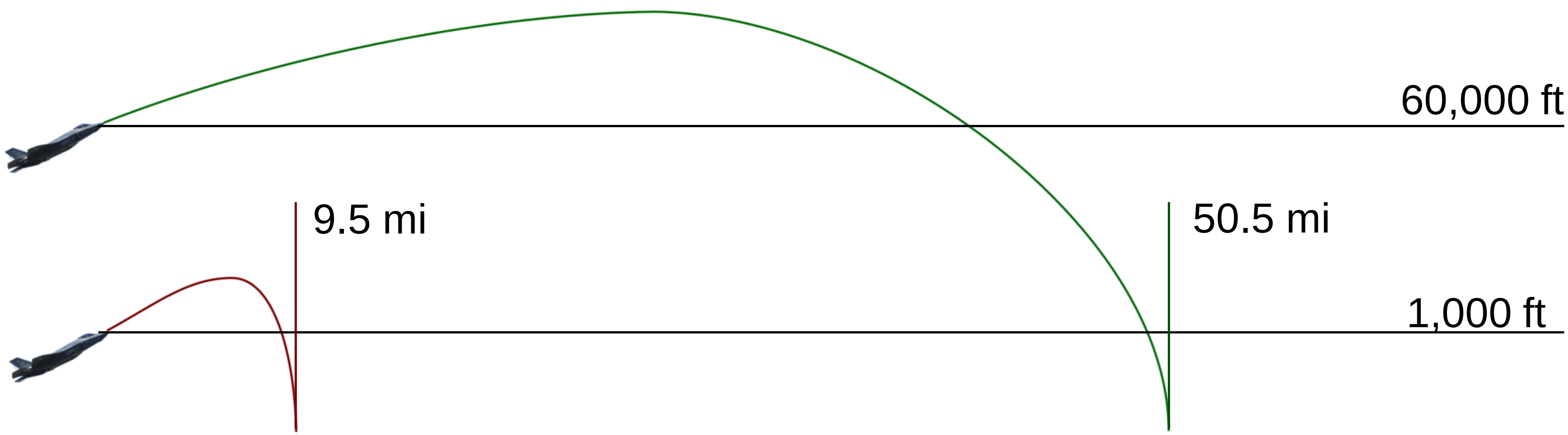
- Existing Loadout F-35A
  - 14 x AIM-120
  - 2 x AIM-9
  - 180 x 25mm
- GAU-12/U retrofit

[7]

- Simulated retrofit PGU-25 series:
  - Direct fire near sea-level

	PGU-25	25mm MASS GHLM	% Change
Projectile Mass (kg)	0.18	0.18	~
Effective Range (mi)	1.42	2.19	+54%
Ballistic Coefficient (PGU reference form factor)	1.26	2.10	+67%

  - Indirect



- F-35A vs GHLM Equipped Fighter (XF-36)
  - AAA code used for both aircraft, then scaled based on known F-35A procurement cost per airframe. Assumed 1768 airframes at uniform price

Program Level Costs ($ billions)		
	F-35A	XF-36
RDT&E Total	$25.5B	$13.6B
Manufacturing Cost (Program)	$110.4B	$82.2B
Acquisition Cost	$115.9B	$86.3B
Program Operating Cost	$235.5B	$225.5B

Airframe Level Costs		
	F-35A	XF-36
Unit Price (millions)	$ 80.0M	$ 56.5M
Operating Cost per Flight Hour	$ 29,600	$ 28,400

MASS Guided Hard Launch Munition Potential on Aerial Platforms

- Ranges comparable to modern air-to-air missiles
- Expanded engagement range envelope
- Increased number of targets engaged
- Effectively increase caliber of aircraft without retrofit of gunnery system
- Implications for airframe defense and future aircraft design
- Reduced cost/kill
- Enhanced survivability and more rounds allow fewer aircraft to carry out the same mission

Enabling Technology: MASS

- Secure commercial partner for MASS tech. transfer
- Work with commercial partner to capture aerial munitions market

Acknowledgements

The University of Kansas
Department of Aerospace Engineering

The Madison and Lila Self Graduate Fellowship

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Questions

2019 Fuze Conference

THE VALUE OF PERFORMANCE.

NORTHROP GRUMMAN

Providing for Continued DSU-33D/B Viability

May 15, 2019

Dave Liberatore
Program Manager

DSU-33 Overview

NORTHROP GRUMMAN

Doppler Radar Proximity Sensor

- Detects one factory-preset Height of Burst (HOB) and provides fire pulse signal to FMU-139 series and FMU-152 fuzes
- Compatible with M117 & Mk80-series general-purpose warheads, including JDAM variants

Performance Parameters

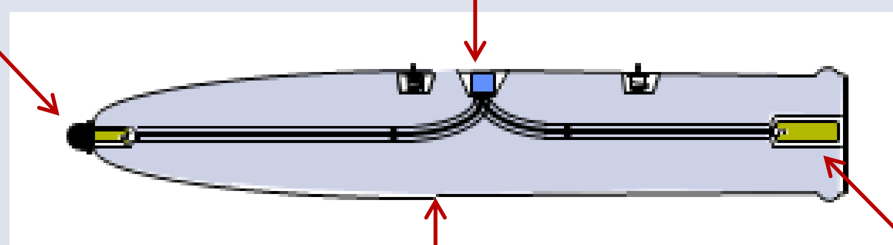
- Height of Burst: 14-26 feet AGL
- Operational Life: 200 sec, min
- Storage Life: 13 years
- Service Life: 5 years outside storage container
- Multiple weapon release: salvo: 6, ripple: 24

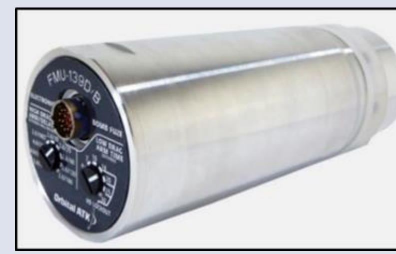
DSU-33 Weapon Configuration (Typical)

NORTHROP GRUMMAN

DSU-33 Sensor

FZU-48/55/63 Initiator or MK122 Switch





FMU-139 or FMU-152 Fuze

Mk-80 Series or M117 GP Bomb

DSU-33 History

- 1970's: Desire to improve performance of Mk 20/Mk 43 Target Detectors
- 1980's: Motorola develops DSU-33A/B
- 1990-1995: Motorola manufactures DSU-33A/B for USAF
- 1998: DSU-33D/B JDAM-compatible design upgrade is completed
- 2000: ATK begins DSU-33B/B production
- 2006: DSU-33C/B producibility upgrade completed & production begins
- 2008: DSU-33D/B qualified and production begins
- 2018: 200,000th DSU-33 Sensor delivered by Northrop Grumman

The Challenge: Maintaining Viability Over A Long Production Run

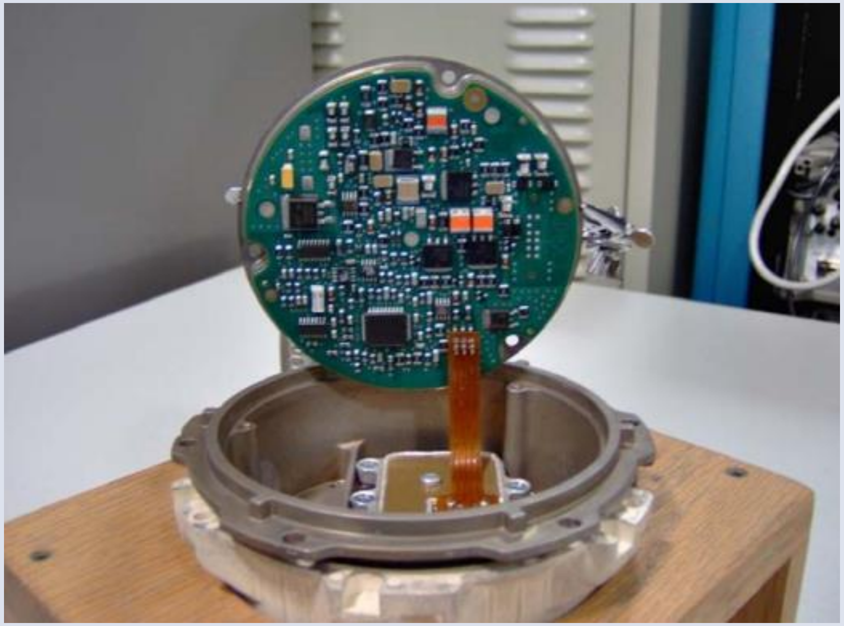
- DSU-33D/B is a mature product in the sustainment phase of it's overall life cycle
  - Both the design and the manufacturing process are well understood
  - C/B and D/B are virtually identical, with > 150,000 produced since 2008

- However, over time multiple factors converge to require changes; even on a stable and successful program like DSU-33:

  - **Obsolescence:** Suppliers drop products & exit markets altogether
  - **Economics:** Increasing costs force changes to maintain profitability
  - **Failures:** A long production run will promote failure mechanisms that likely would never occur during a short program life

Examples: Obsolescence

- The commercial electronics industry continues to evolve rapidly
- Specific parts become scarce or obsolete; or entire product lines are discontinued
- Situations Northrop Grumman has successfully managed include:
  - Obsolescence of 2 Transistors
  - Obsolescence of 3 Thermistors
- Mitigation strategies included:
  - Monitoring upcoming obsolescence via tools like Part Miner
  - Supplier dialogue
  - End of Life (EOL) buys
  - Selection of alternative parts
  - Qualification of alternatives via Component and Sensor-level testing, and analysis



Examples: Economics

- Suppliers may increase pricing to the point where a legacy part no longer is affordable

- Supplier quality may deteriorate to the point where their continued use is no longer affordable (e.g. unacceptable costs of nonconformance)

- Situations Northrop Grumman has successfully managed include:
  - Desiccant capsule pricing and quality
  - Pricing of a custom Transistor

- Mitigation strategies included:
  - Selecting and qualifying a COTS Transistor
  - Developing and qualifying a custom desiccant pack (shown at right)

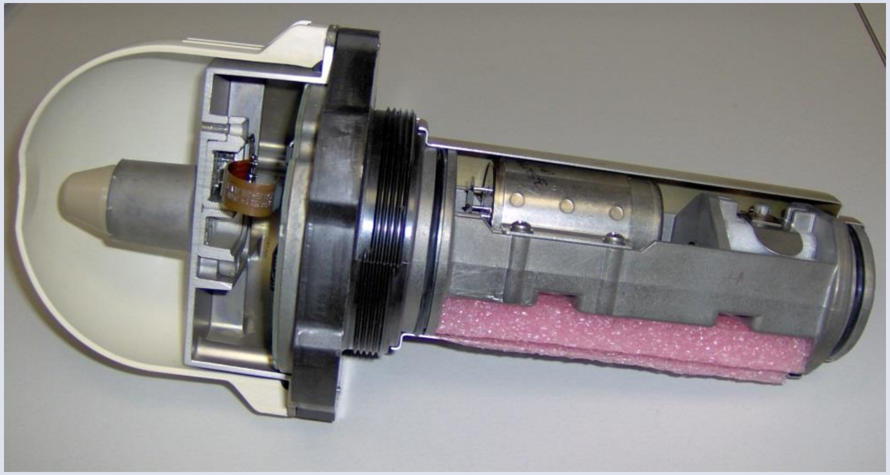
Examples: Failure Mitigation

- Even the most robust product development efforts will be unable to prevent or detect all failure mechanisms

- Long production runs, involving tens or hundreds of thousands of units, inevitably introduce the “Cumulative Effect of Variation Over Time”

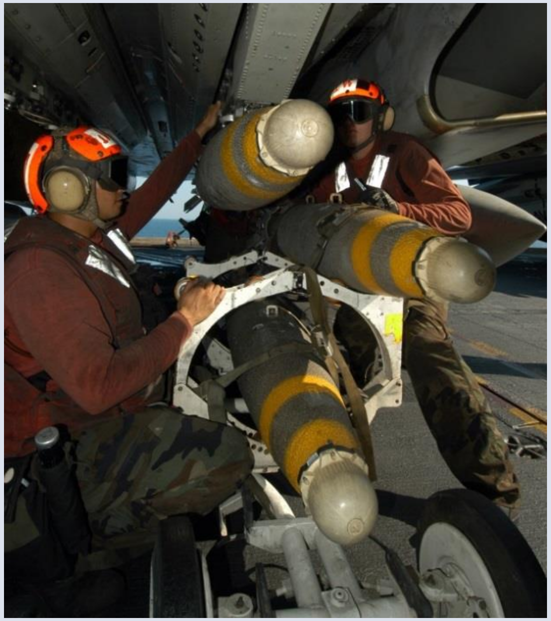
- Impact: End-item performance problems will arise during production. Situations Northrop Grumman has successfully managed include:
  - Fire pulse variability
  - Battery Initiation difficulties

- Mitigation strategies include:
  - Revising and clarifying requirements
  - Qualifying an improved Battery and Battery Igniter
  - Screening & binning key components to improve production test yields



Keys to Success

- **Product Knowledge:** As the Government's industry partner during development and high-rate production of the last 3 DSU models, we understand the Sensor
  - Northrop Grumman has the full-service capability to resolve any issue
- **Program Continuity:**
  - DSU-33 production has been essentially continuous for almost 19 years
  - DSU-33 Support Team staffing has been managed carefully to ensure success
- **Customer Support:**
  - DSU-33 has always had a strong Government/Contractor IPT
  - Ongoing cooperation from the USAF (EAFB and HAFB), Army, and Navy has enabled success
  - Frank and open communication has fostered partnership and trust



The Future for DSU-33D/B

- The program is in the final year of the current U.S. Government FRP4 contract:
  - Deliveries to the USG will conclude in 2020

- International interest remains high, resulting in high likelihood of ongoing commercial sales

- A contingency requiring a future U.S. procurement is possible

- For these reasons, Northrop Grumman is working closely with the Government to ensure that the DSU-33D/B Technical Data Package (TDP) remains up-to-date and viable to support ongoing production

- The DSU-33 production line, Support Team, and experienced supplier base will remain in place for the foreseeable future

Summary

- DSU-33 has been one of the most successful air weapon fuzing/sensor programs in the last 40 years
- The program has been successful because of its maturity, supported by ongoing engineering and TDP updates
- Northrop Grumman remains committed to maintaining the capability of the DSU-33D/B to support ongoing customer requirements
- DSU-33 will remain a viable proximity sensor solution for many years
- Thank you!

THE VALUE OF PERFORMANCE.

NORTHROP GRUMMAN

EAS – Munitions

62nd NDIA Annual Fuze Conference
Buffalo, NY
May 13-15, 2019

Innovative Developments in Carbon Cathode Matrix Materials for Li/$SOCl_2$ Reserve Batteries

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Agenda

- $Li/SOCl_2$ Reserve Battery Applications & Characteristics
- $Li/SOCl_2$ Electrochemistry
- Role of Carbon Matrix Material
- Development of New Material
- Mechanical Strength
- Porosity Metrics
- Electrochemical Performance
- Process and Formulation Tradeoffs

Li/$SOCl_2$ Reserve Battery Applications

Lithium oxyhalide battery applications include

- Artillery
- Air delivered Weapons
- Mortar Munitions
- Missiles/Rockets
- Barrier Munitions

Li/$SOCl_2$ Reserve Battery Characteristics

- Long shelf life: > 20 years
- Ability to be fabricated in a variety of configurations
- Large usable temperature range (-60°C to 85°C)
- Open circuit voltage of 3.7 V per cell
- Flat discharge profile
- High energy density
- Moderate rate capability (typical maximum current density of 50 mA/cm2)

Li/$SOCl_2$ Electrochemistry

Lithium: Solid metal anode (where oxidation occurs)

Thionyl Chloride: Liquid cathode serving as its own solvent (catholyte) (where reduction occurs)

Anode Reaction:

$$Li_{(s)} \rightarrow Li^+ + e^-$$

Cathode Reaction (at carbon surface):

$$2SOCl_{2\,(l)} + 4\,e^- \rightarrow SO_2 + 4Cl^- + S$$

Overall reaction:

$$4Li + 2SOCl_2 \rightarrow 4LiCl_{(s)} + S + SO_2$$

Role of Carbon

Overall reaction:

$$\underset{\text{Anode}}{4Li} + \underset{\text{Cathode}}{2SOCl_2} \rightarrow \underbrace{4LiCl_{(s)} + S + SO_2}_{\text{Discharge Products}}$$

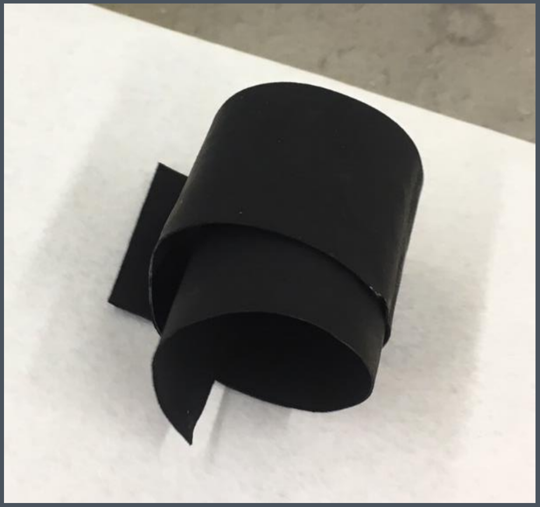
- Carbon supplies energetically favorable deposition sites for the discharge product: LiCl
- Typically referred to as the cathode matrix material even though it does not directly contribute any electrochemical potential or energy to the system
- The carbon presence and specific properties influence the cell's realized energy and rate capability – it is almost always the limiting reagent
- This occurs due to its role as a facilitator in the discharge reaction at the carbon surface
- Made up of carbon and PTFE. The PTFE acts as a binder.

Relevant Carbon Parameters

Carbon properties which facilitate the maximum amount of deposition sites for the LiCl discharge product, while maximizing mass and charge transfer rates will result in a cell with optimal electrochemical performance

These metrics consist of:

- Porosity
- Pore volume
- Pore diameter
- Tortuosity
- Surface area
- Density
- Conductivity
- Overall Formulation/'Active' Material



Sample of carbon matrix material produced at EAS

Development of New Material

Goals
- Improve electrochemical performance
- Produce production-friendly material in both handling and production capabilities

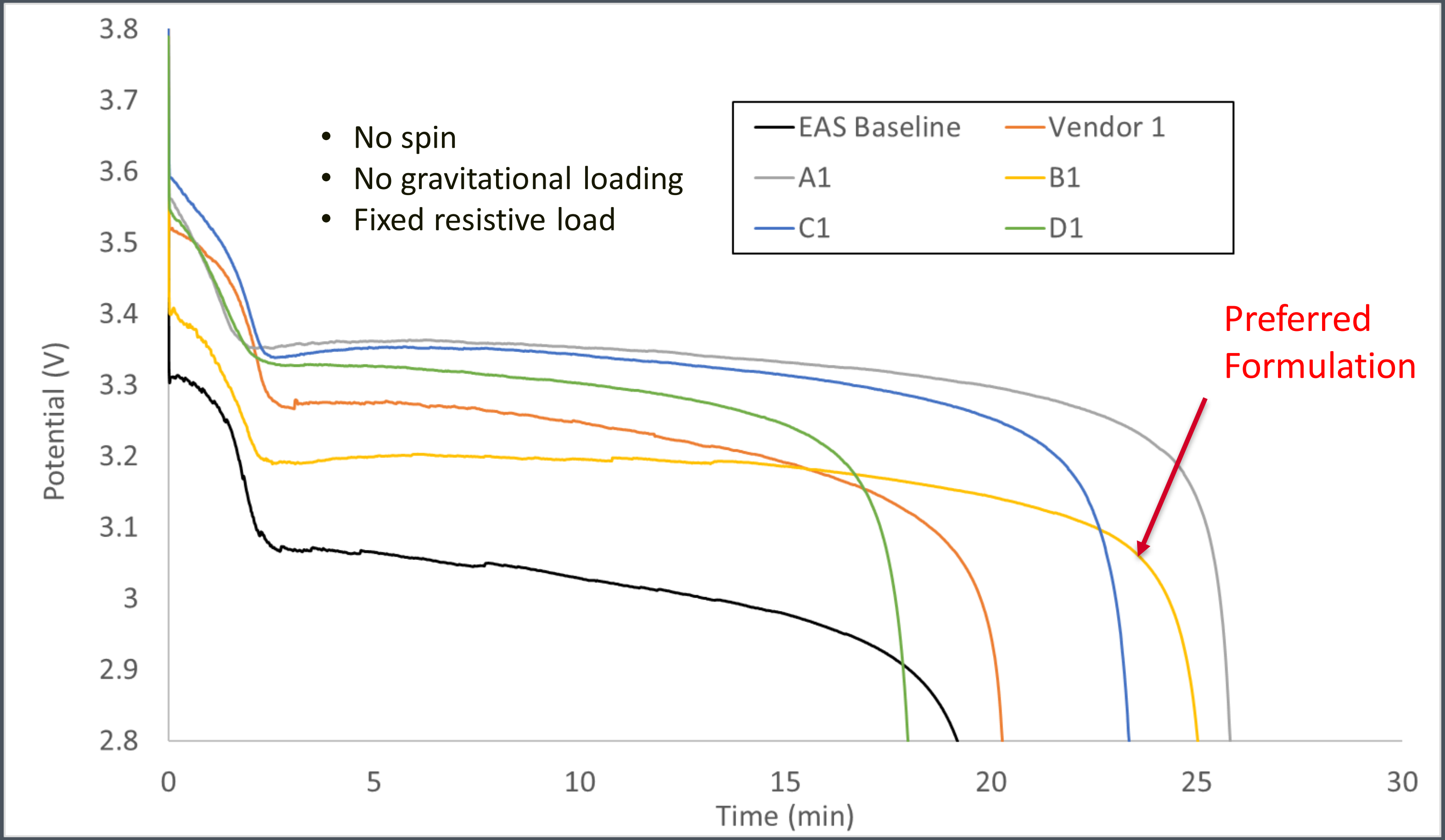
Theory – carbon matrix material consists of high surface area carbon and PTFE. The following can be varied to influence the mechanical and electrochemical performance metrics

- Carbon/PTFE ratio – Developed a process for 4 formulations (A, B, C, D)
- Handling of the material after introduction of the components (Method 1 or 2)

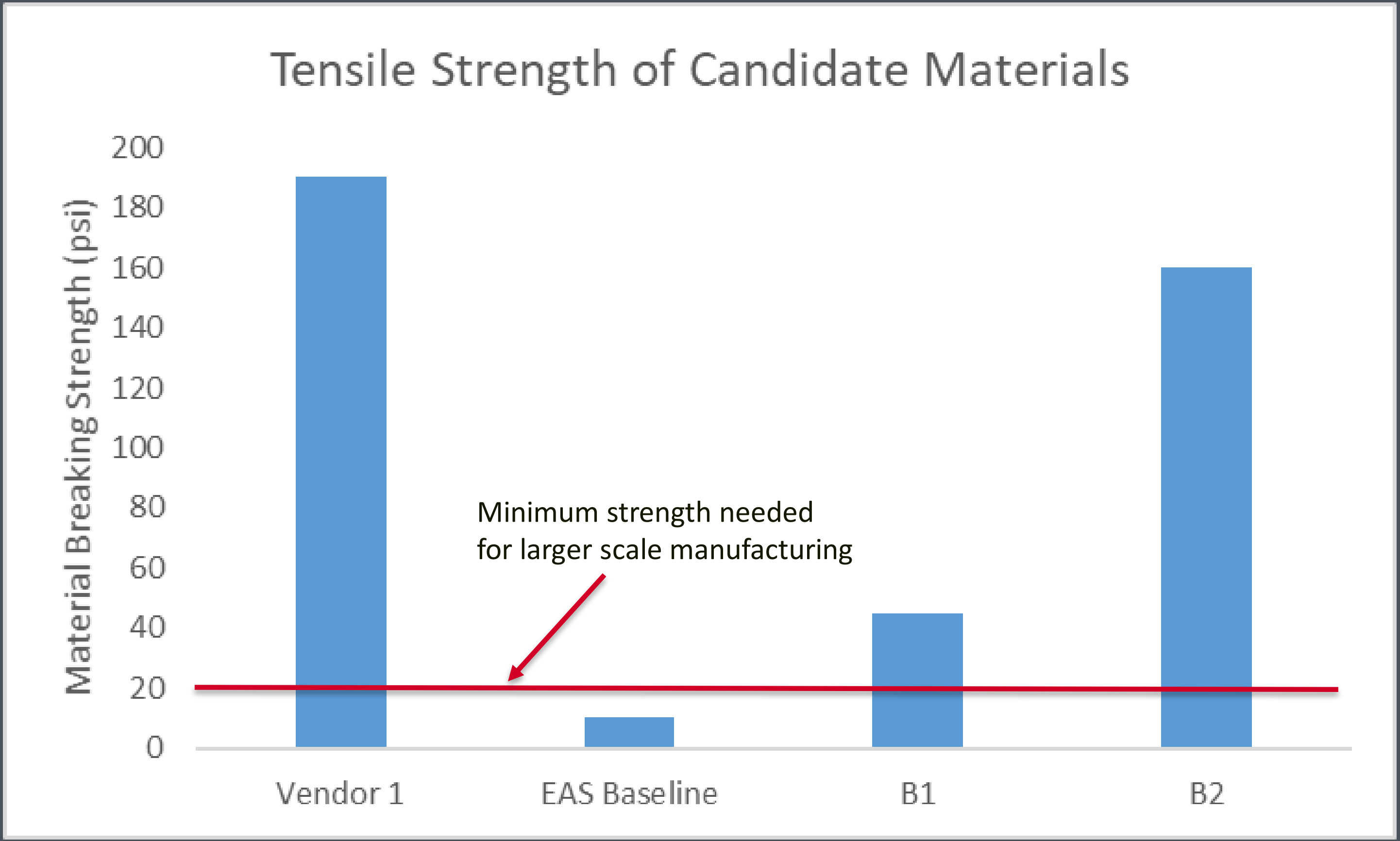
Sample Identification		
Carbon/PTFE Formulation	Method	
	1	2
A	A1	-
B	B1	B2
C	C1	-
D	D1	-

Electrochemical Evaluation of PTFE Loading In Single Cell Tests

Initial evaluations performed in EAS' G2666B1 device at 63°C showed up to 25% improvement in run time to EAS Baseline and Vendor 1 material. using no spin or gravitational loading.



Mechanical Strength



- Mechanical strength affects manufacturability, and handling characteristics
- Benefits and drawbacks exist for each material

Porosity Metrics

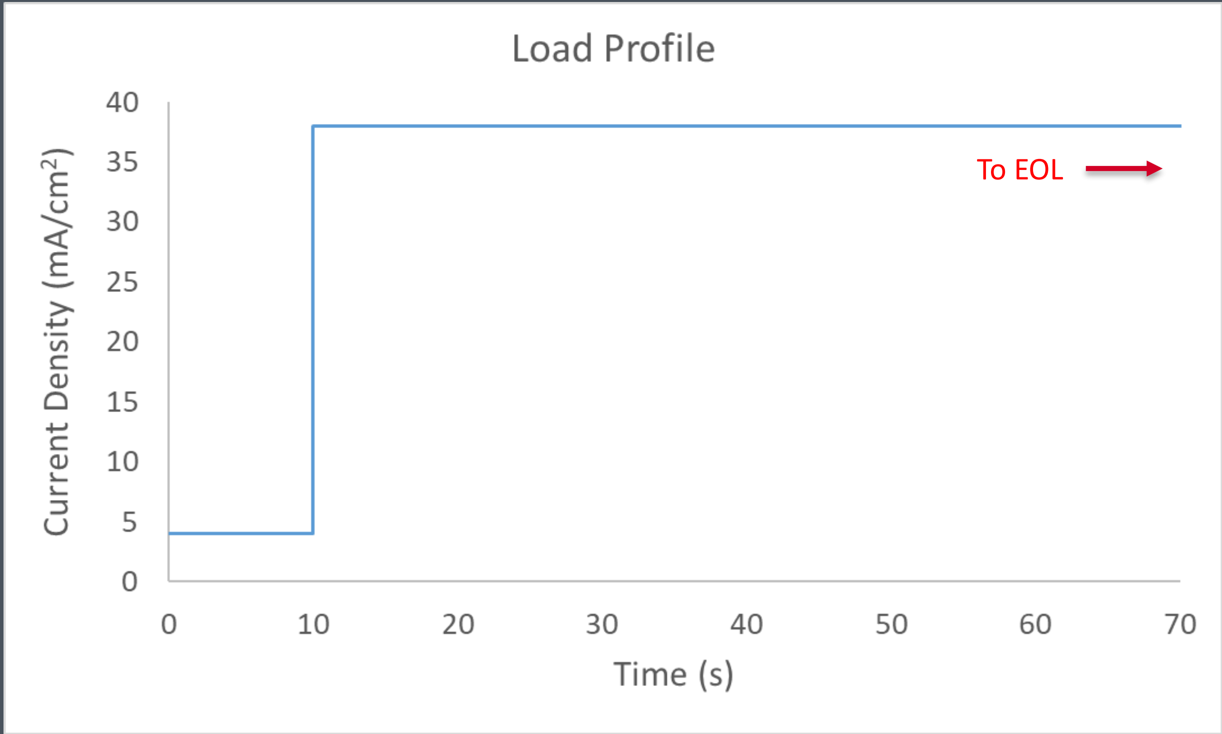
Matrix Material	Porosity Metric				
	Surface Area (m^2/g)	Porosity (%)	Density (g/mL)	Pore Volume (mL/g)	Avg Pore Diameter (um)
Vendor 1	12	46	0.40	0.19	0.74
EAS Baseline	14	51	0.36	1.41	0.405
EAS B1	62	77	0.44	1.93	0.125
EAS B2	58	62	0.68	0.93	0.065

- Newly developed matrix material formulations exhibit significantly more favorable porosity metrics
- As long as mass transfer is not inhibited by small pore diameter or high tortuosity, we expect to see better electrochemical performance in the new formulations

Electrochemical Performance Comparison

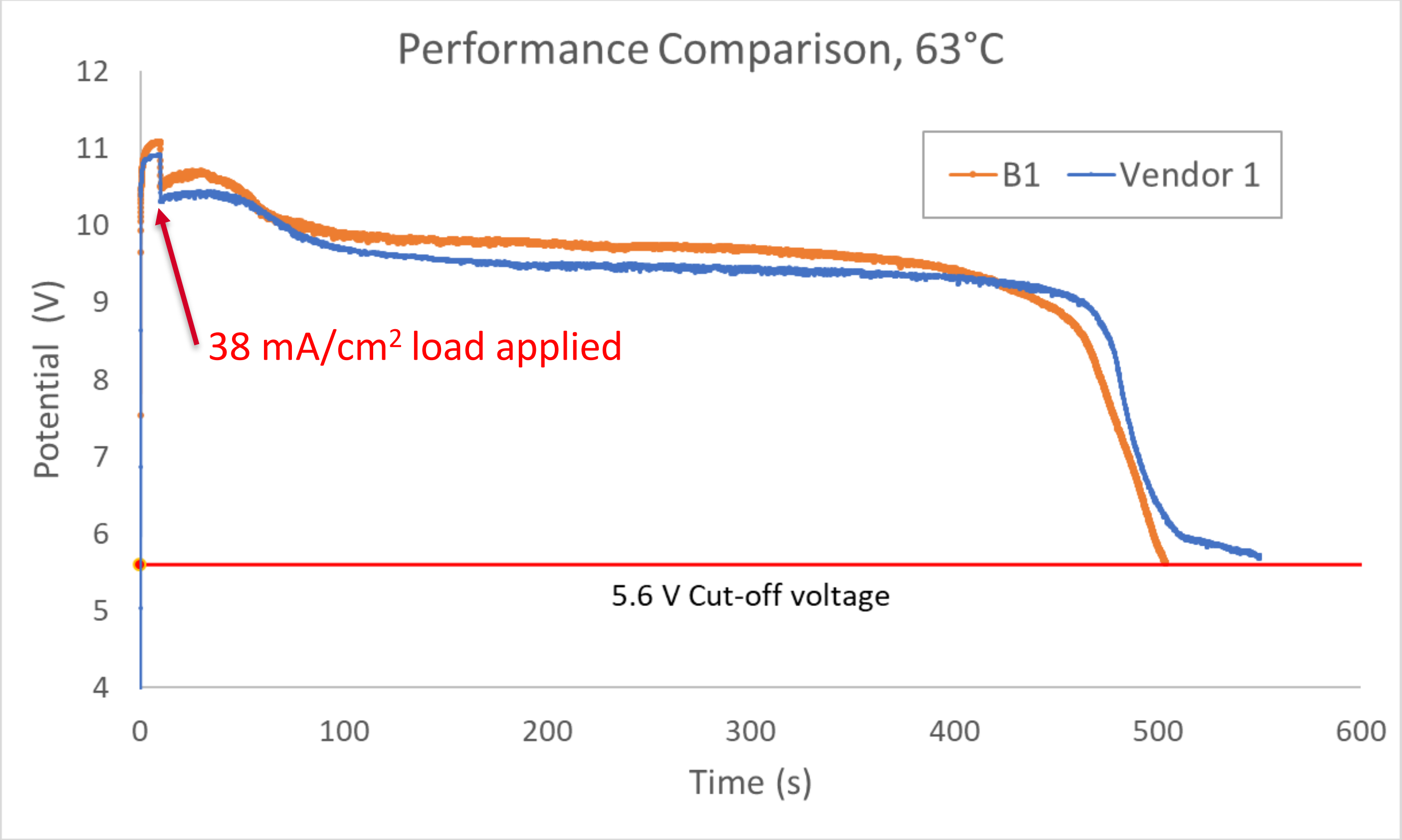
Application-representative environment test setup:

- Built into an existing EAS device with 3S2P configuration
- Tested in a spin-capable airgun at EAS
- Activated via gravitational loading
- Activated into 80 RPS spin
- Discharge rate of 38 mA/cm2



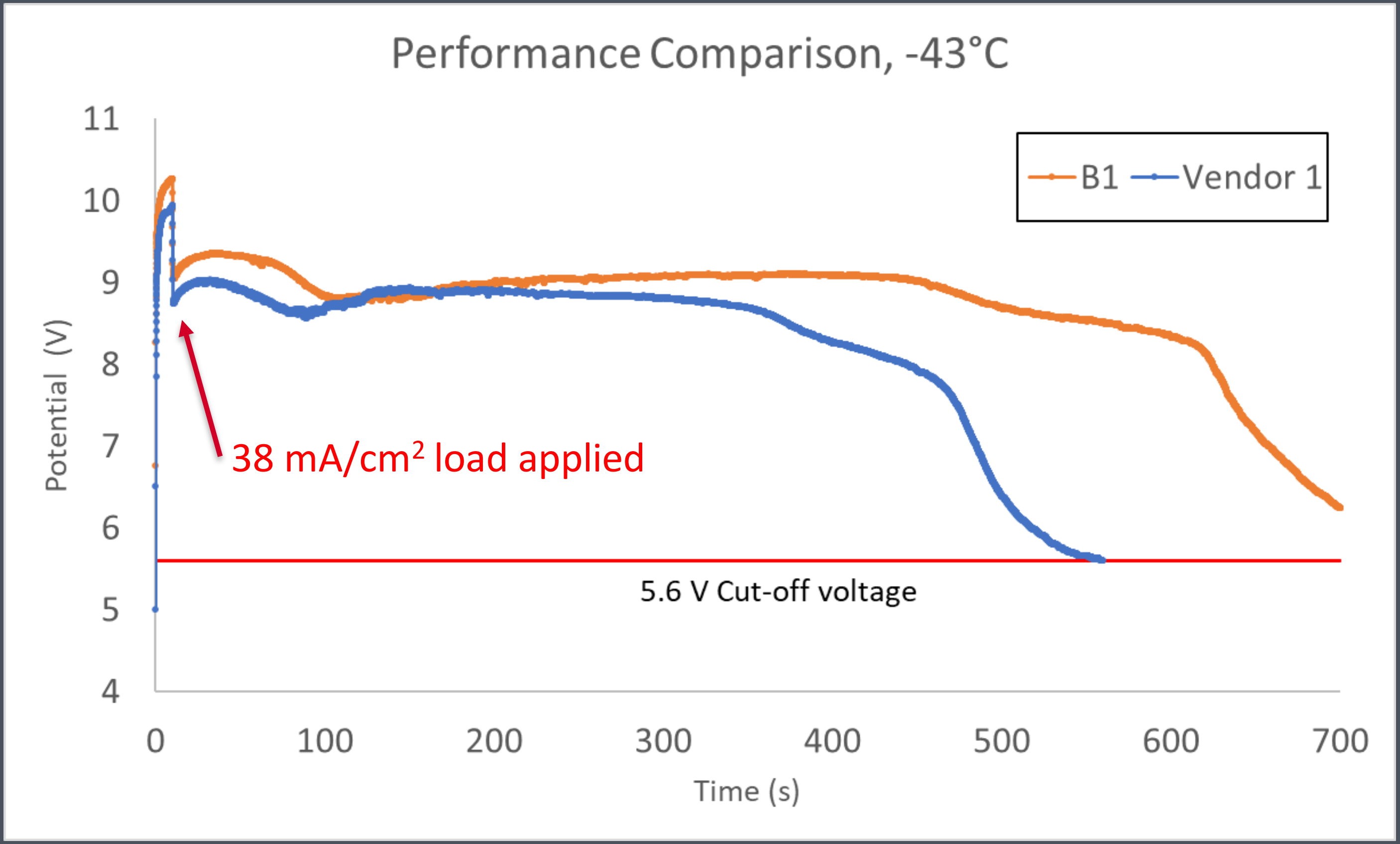
Electrochemical Performance Comparison, 63°C

- Comparable run time seen at 65°C
- New formulation typically runs at slightly higher voltage



Electrochemical Performance Comparison, -43°C

- New formulation runs ~35% longer at -43°C.
- New formulation typically runs at slightly higher voltage



Process and Formulation Tradeoffs

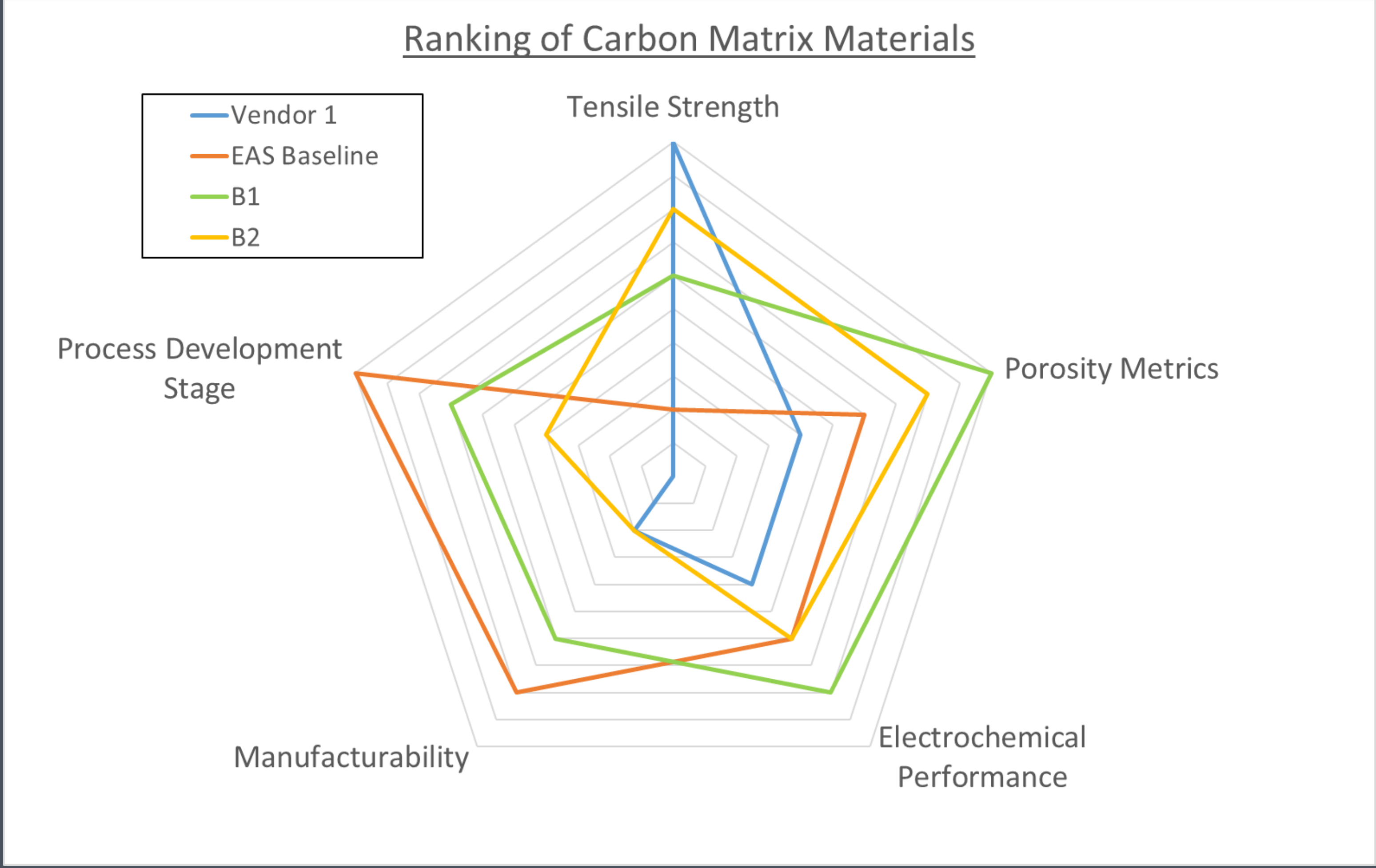
- Vendor 1 material
  - Greatest tensile strength
  - Poor porosity metrics possibly influencing performance.
  - Risky for EAS to rely on a sole source with no control over it

- EAS Baseline
  - Low tensile strength, impacts ability to use at scale
  - Easy and relatively quick to manufacture
  - Serviceable electrochemical performance

- Formulation B1
  - Serviceable tensile strength for scalable production operations
  - Great porosity metrics
  - Great electrochemical performance, especially at cold temperatures

- Formulation B2
  - High tensile strength
  - Good porosity metrics
  - Not very scalable, lots of processing required

Process and Formulation Tradeoffs



Conclusion

- Successfully developed a new carbon cathode matrix material that is compatible with Li/$SOCl_2$ reserve battery chemistry
- Formulation B1 performs better electrochemically than baseline and commercially available material (likely due to porosity metrics), especially at cold temperatures
- The new process is able to create material with sufficient tensile strength to be used in higher-volume production (Formulation B1 and B2) and compete with commercially available material for electrochemical performance and supply chain reliability
- Future work will revolve around further characterization of Formulation B1 and scale up of the manufacturing process

Hardened, Compact and Fast:
Adaptive Flight Control Actuators for Guided Hard-Launched Munitions

Dr. Ron Barrett
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Adaptive Aerostructures Laboratory Director

Ms. Lauren Schumacher
Self Graduate Fellow & Ph.D. Candidate

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The University of Kansas, Lawrence, Kansas

NDIA 62nd Annual Fuze Conference
13 – 15 May 2019
Buffalo, NY

Paper No: 21779

Outline:

I. Motivation

II. Background

III. New Classes of Adaptive Actuators

IV. Enabled Systems

V. Future Work

Unclassified Unlimited Distribution

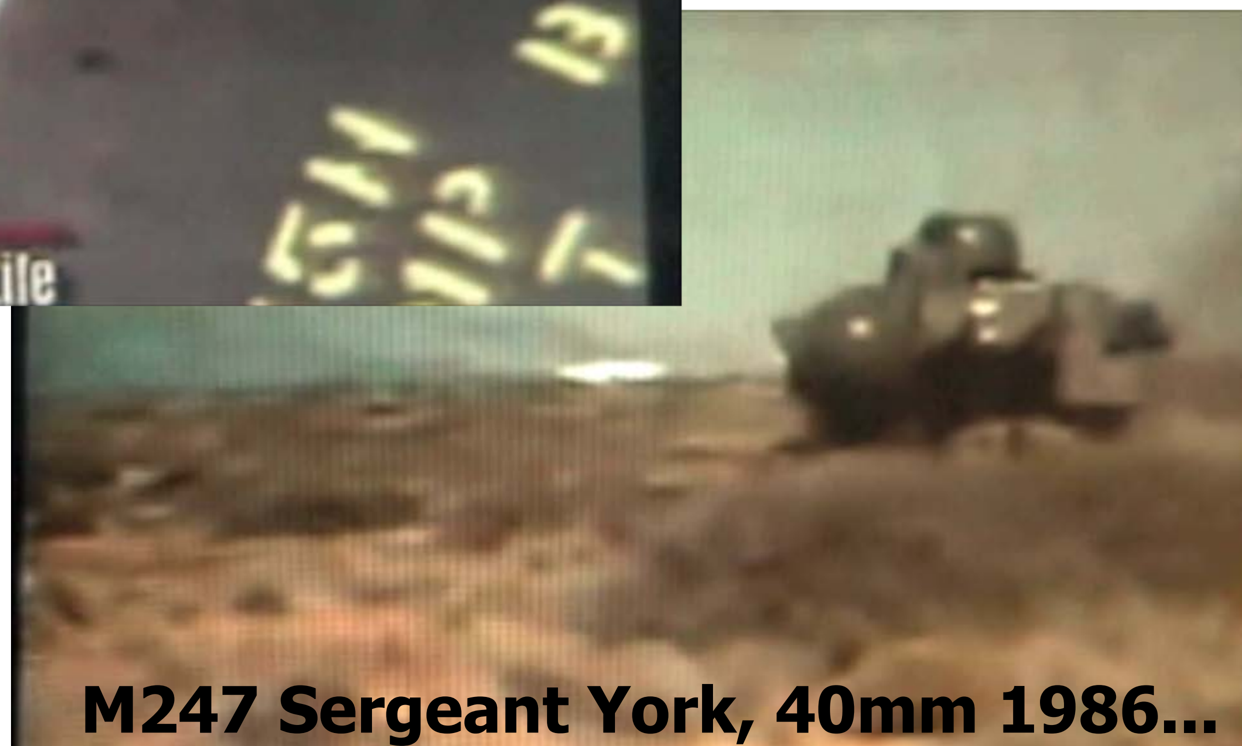
Motivation:

- *New Enabling Technologies*
    - *lower caliber rounds via MASS designs…*
    - *new missions…*
- *Lines blurred: Missiles ↔ Munitions*
- *Large Cost Savings Possible*

Unlimited Distribution

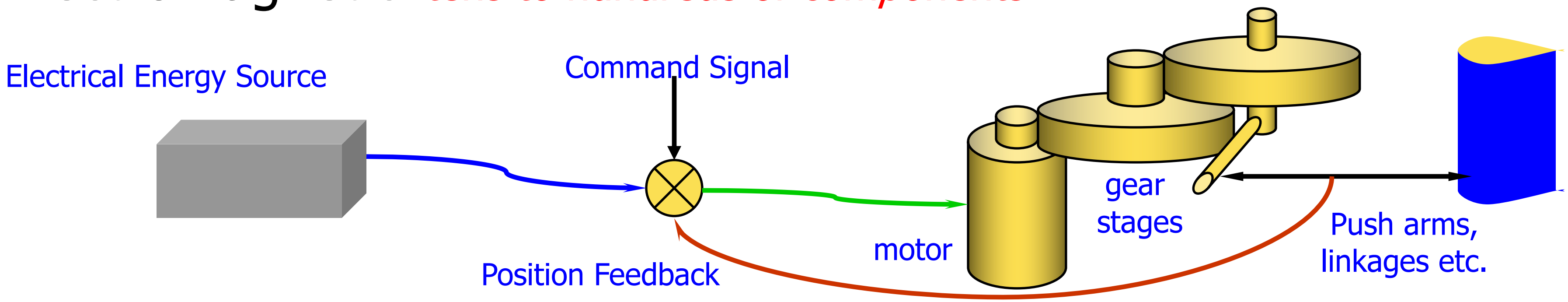
Unclassified

Brief Guided Round History



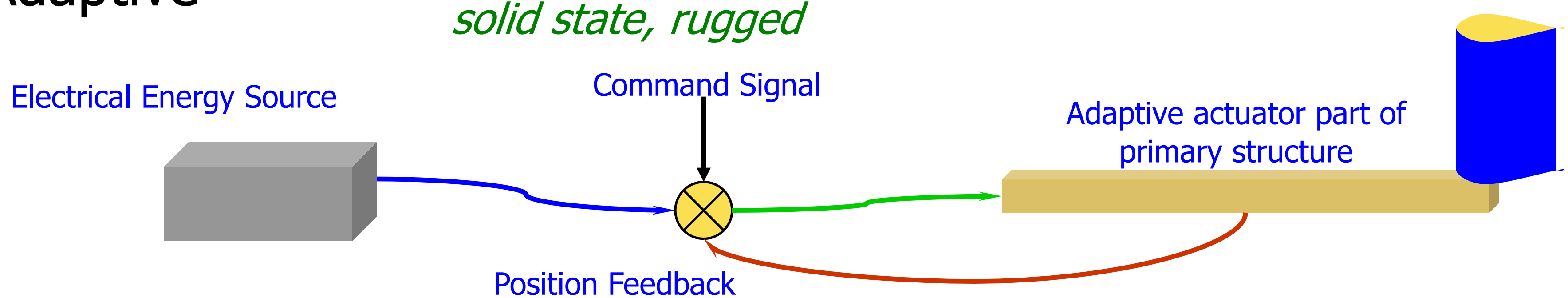
Flight Control Technologies

Electromagnetic *tens to hundreds of components*



Adaptive

solid state, rugged

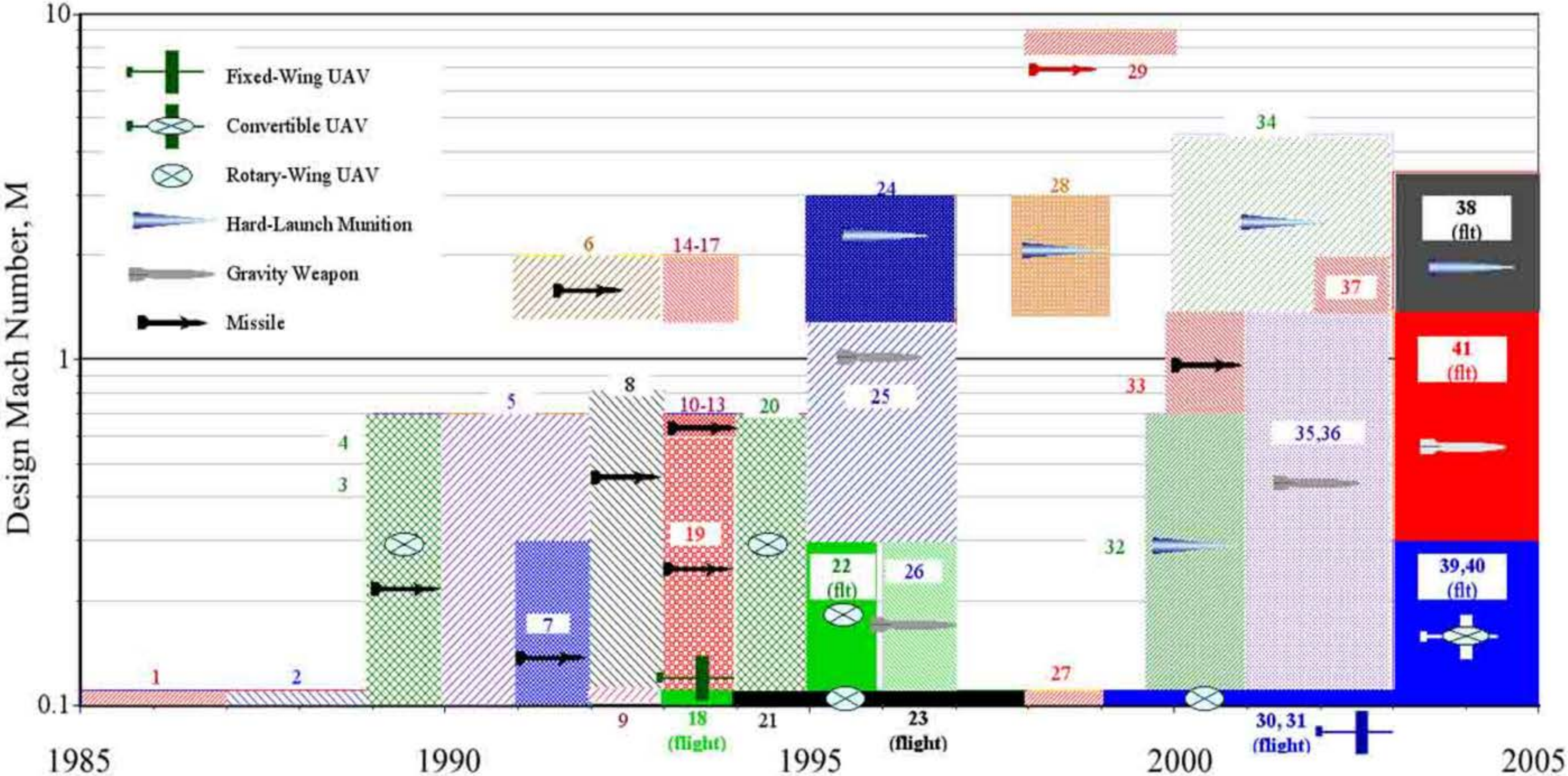


Unclassified Unlimited Distribution

Low Caliber Flight Control Actuator Needs…

- Setback tolerance: 5,000 - 100,000g's
- Balloting, setforward, ringing impervious
- Compatible with supersonic control effectors
- Not affected by atmospherics (rain, dust, dirt, snow, etc.)
- 20 yr storage life
- -40 to +145° F
- Fully proportional deflections
- Lightweight (<1g), Low Volume (<1cc), Low Power (95+% electrical-to-mechanical conversion efficiency)
- High bandwidth (>200 Hz)

Overview of Programs with Lineage to Flying Adaptive UAVs



Unlimited Distribution

Unclassified

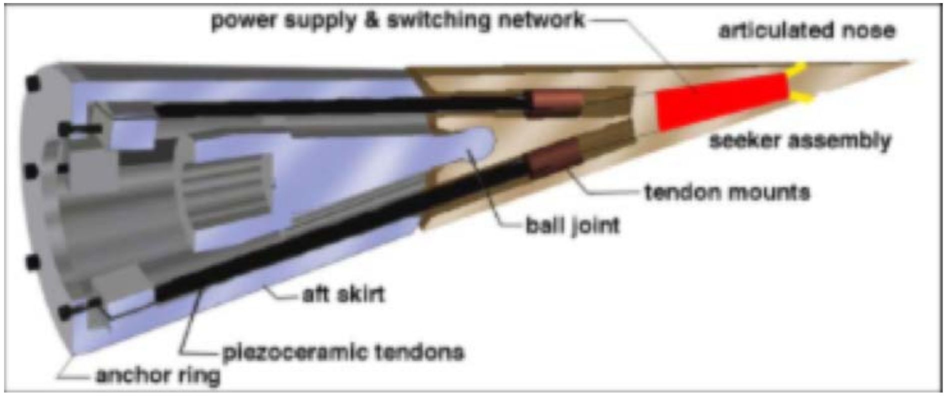
Guiding Lower Caliber Rounds… More History

Barrel-Launched Adaptive Munition (BLAM) Program 1995 - '97

USAF/AFRL-MNAV

- Aerial Gunnery (20 - 105mm)
- Extend Range w/2g maneuver
- (Eglin AFB tests '97)

(Mach 3.3 tests '96-'97)



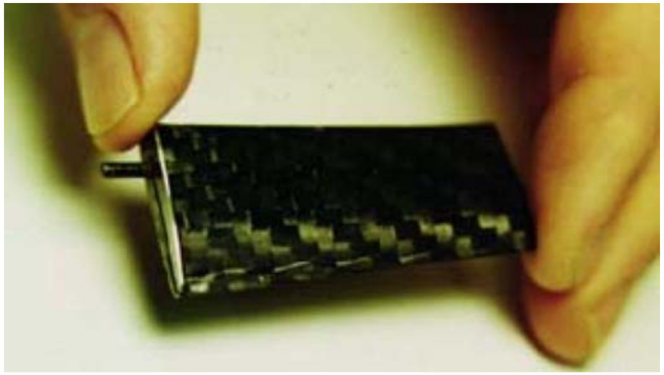
- Increase hit probability
- Increase probability of a kill given a hit
- Reduce total gun system weight fraction

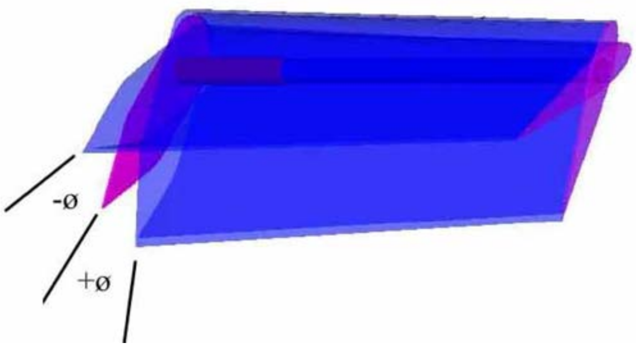
The First MAV… Driving Adaptive FCS

Conventional Electromagnetic

+/- 90° Deflections @ 3 Hz

Adaptive Stabilators





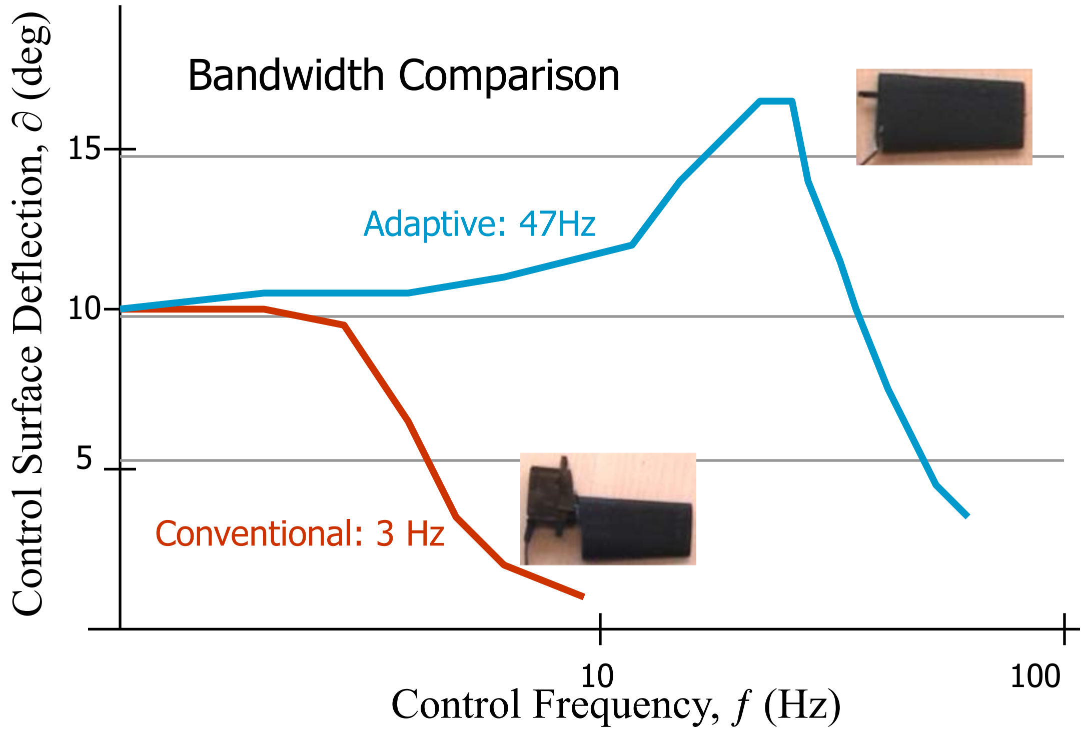
+/-11° Deflections @ >47Hz

Unlimited Distribution

Unclassified

Advanced MAVs:

Driving the need for Adaptive Actuators -- faster, lighter, stronger



Adaptive Surfaces vs. Conventional Servos

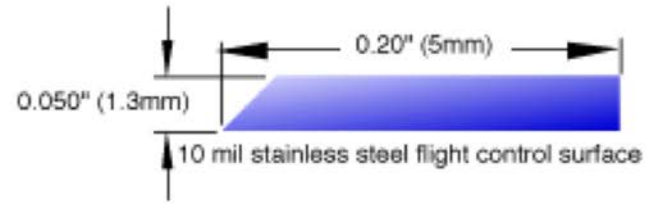
- 96% reduction in power consumption
- 16x increase in bandwidth
- 99.2% decrease in slop
- Order of magnitude reduction in part count
- 12% OWE savings

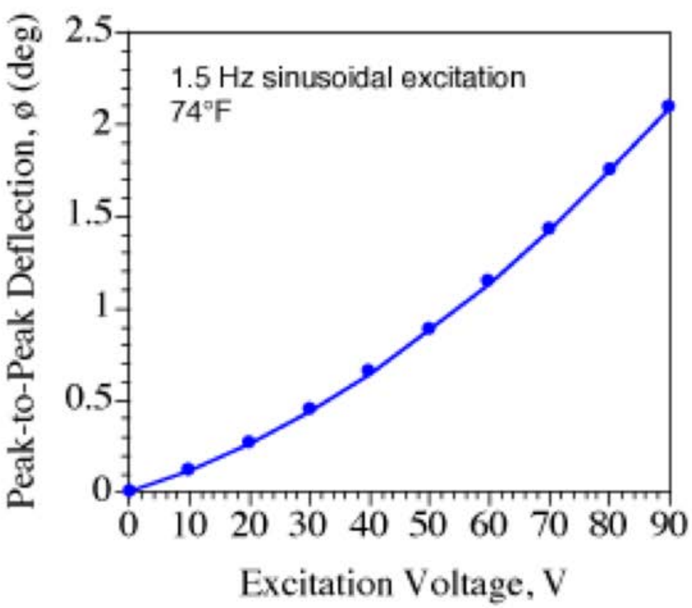
Guiding Small Arms Rounds… More History

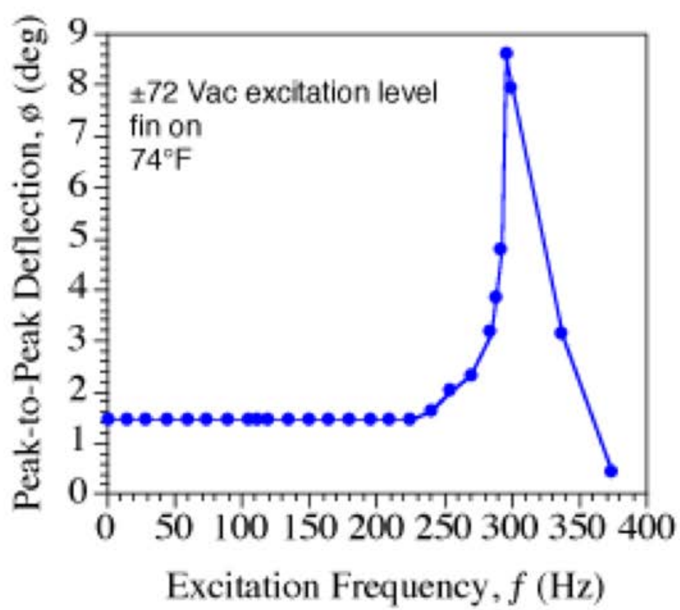
Range-Extended Adaptive Munition (REAM) IRAD

BAT-Lutronix Corp. developed supersonic piezoelectric FCS actuators

Max Power Consumption: 28 mW
Nominal Power Consumption: 3.5 mW
Static Power Consumption: < 1μW
Design Mach Range: 0.8 - 4.5, STP
Design Accelerations: 25k g's





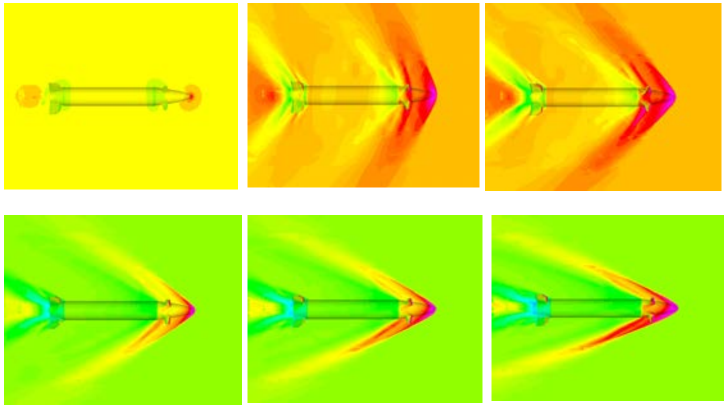


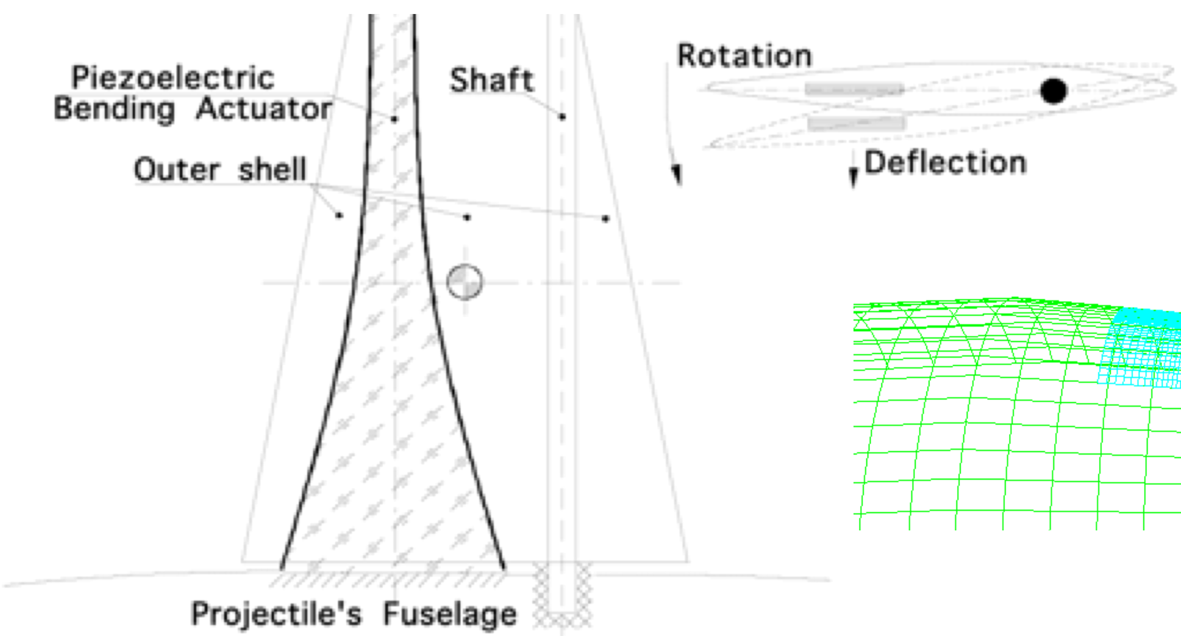
Other Adaptive FCS Efforts

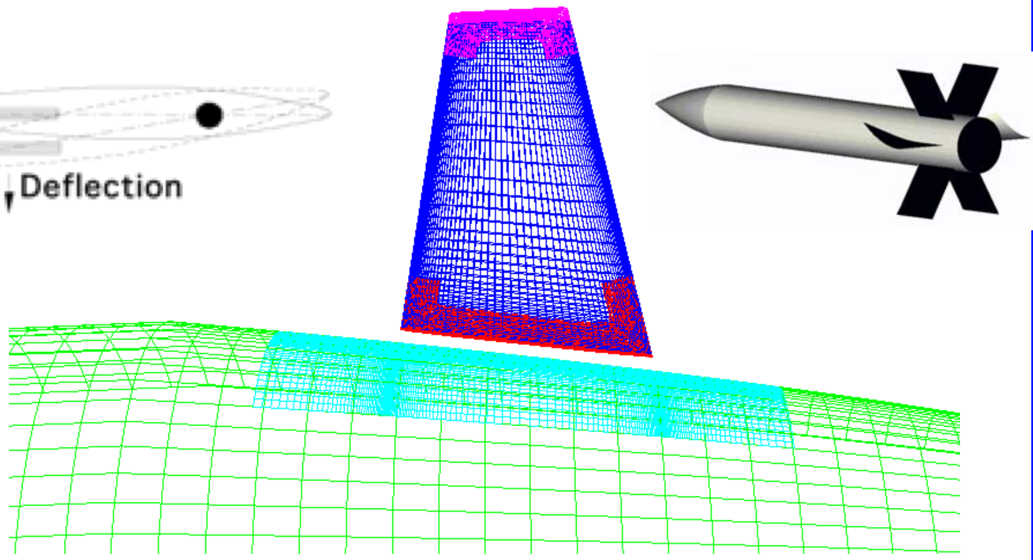
Rabinovitch & Vinson 2000 - present

again... low authority
can't survive balloting, setback unsteady aero...

Now Where???

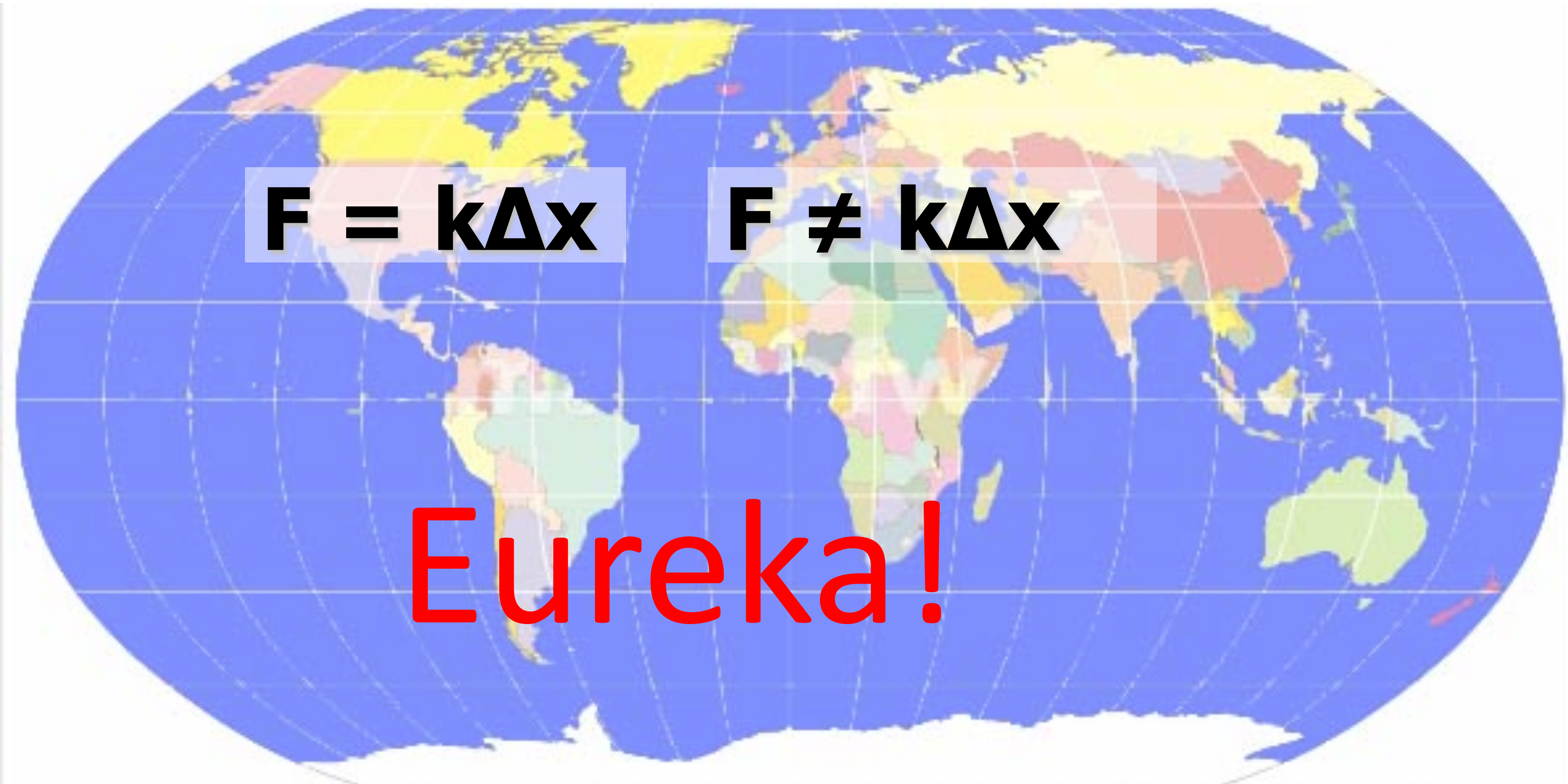






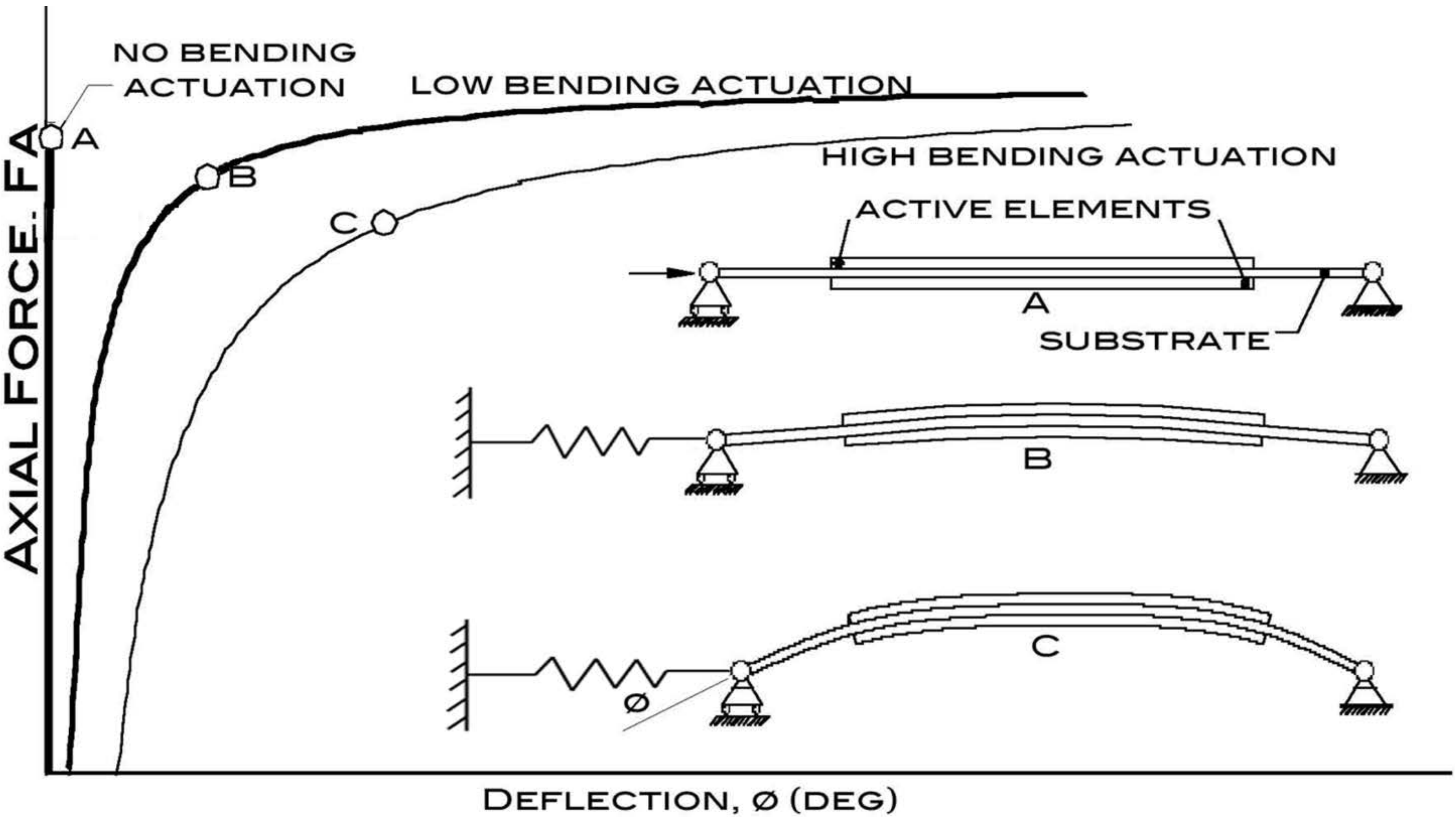
Guiding Hard-Launched Rounds… The Epiphany!

Discoveries from Europe…

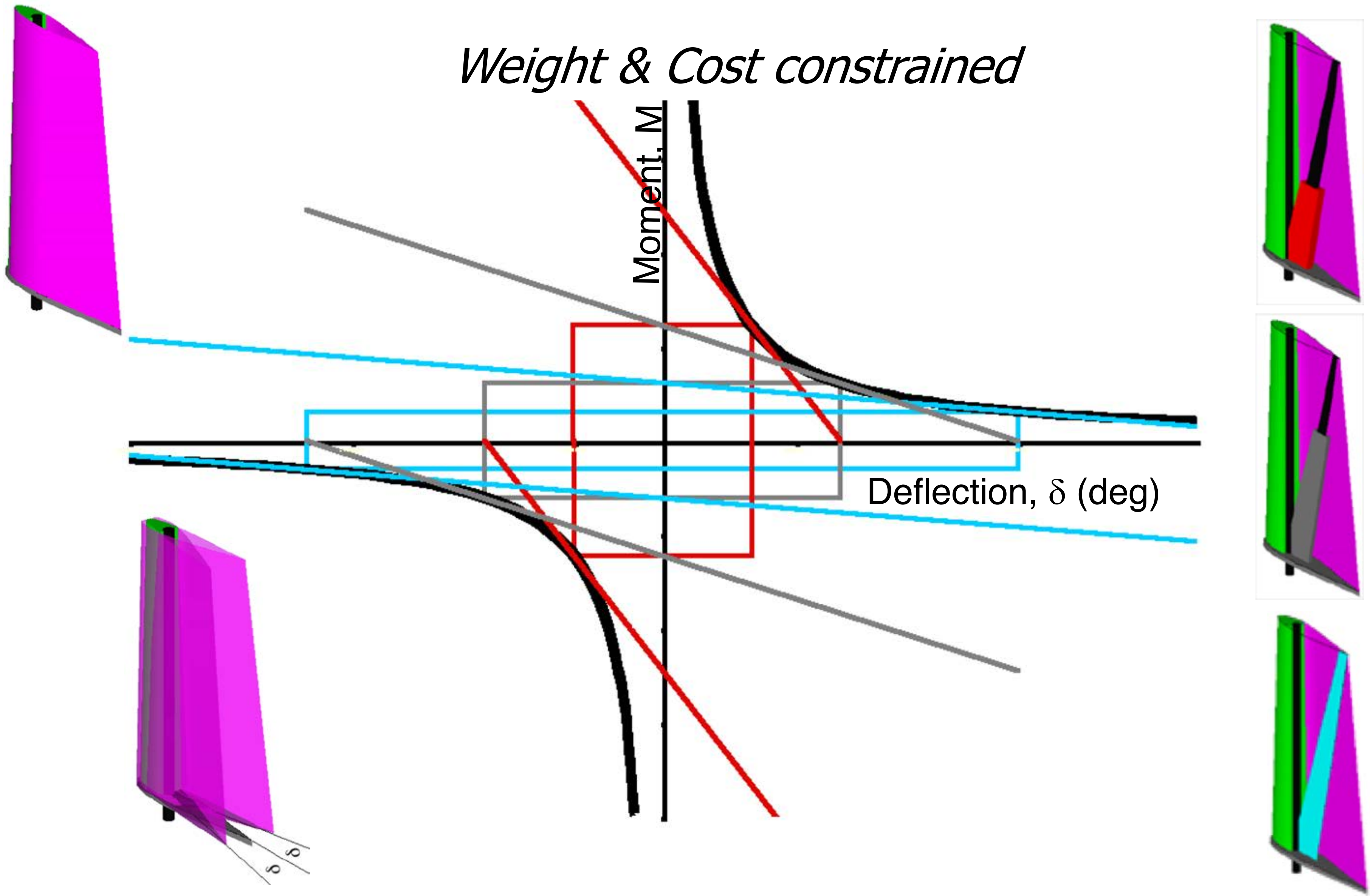


Guiding Hard-Launched Rounds… The Epiphany!

Increasing Moment-Deflection Design Space

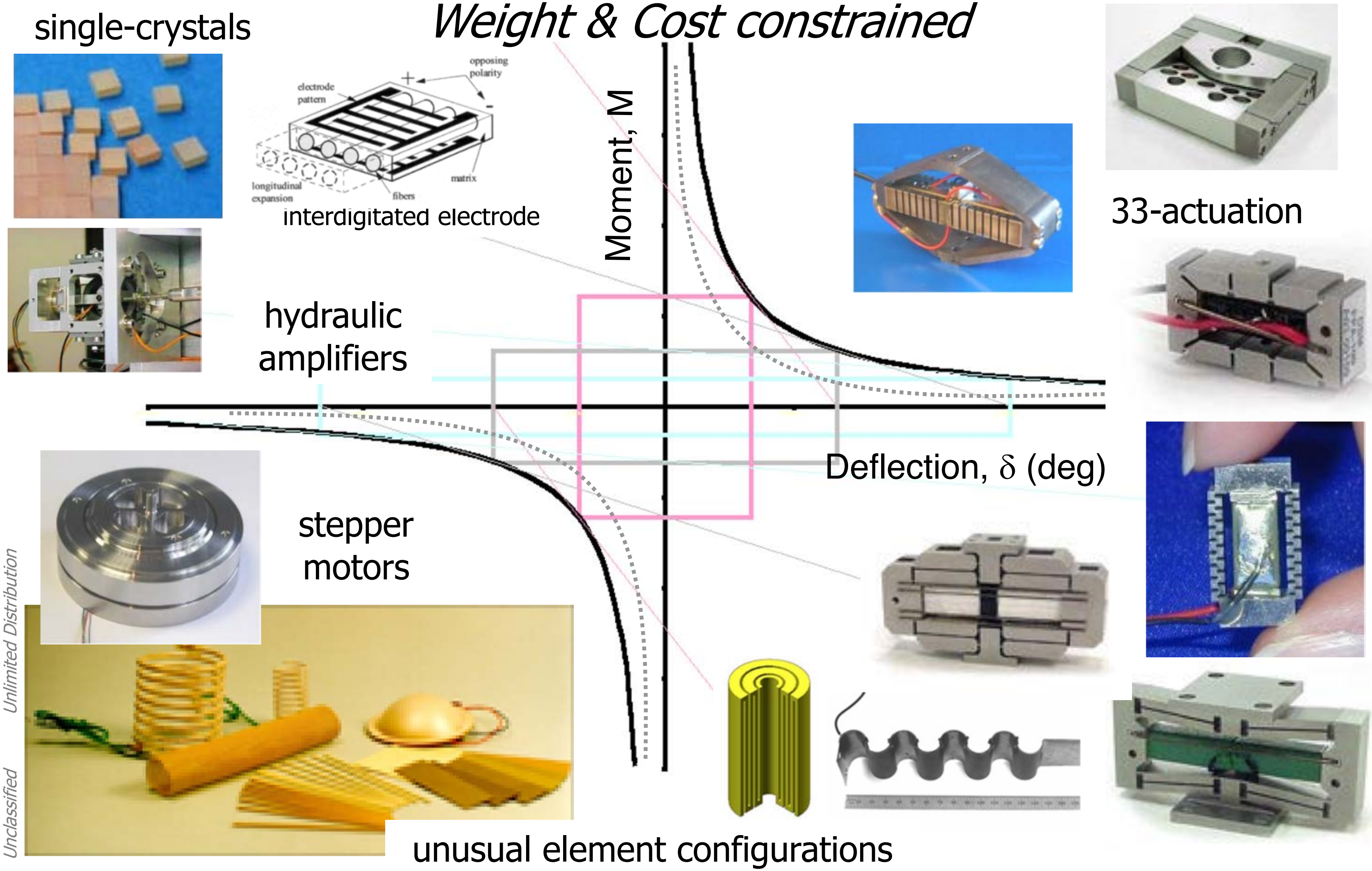


Guiding Hard-Launched Rounds… The Epiphany!



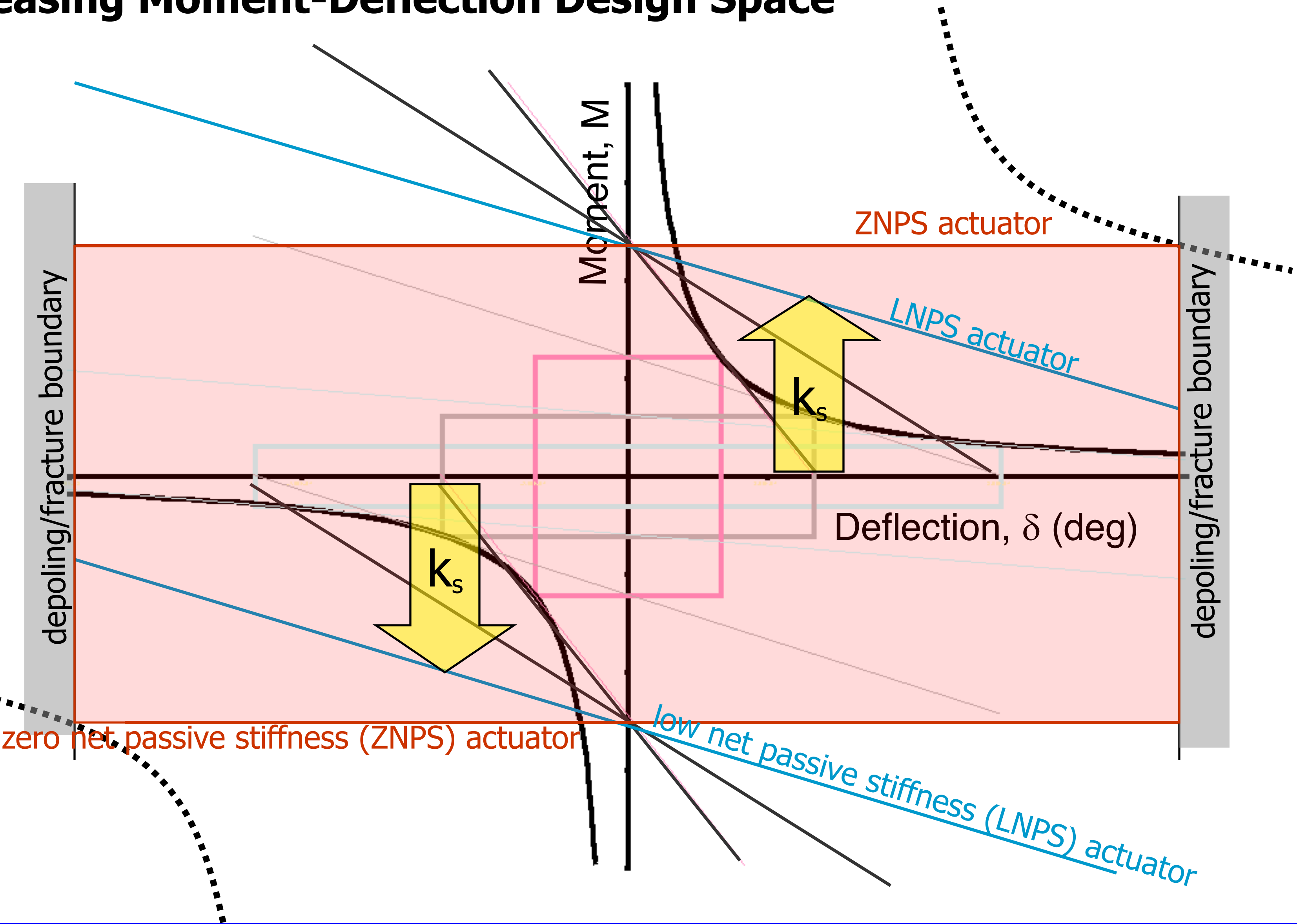
Guiding Hard-Launched Rounds… The Epiphany!

Weight & Cost constrained



Guiding Hard-Launched Rounds… The Epiphany!

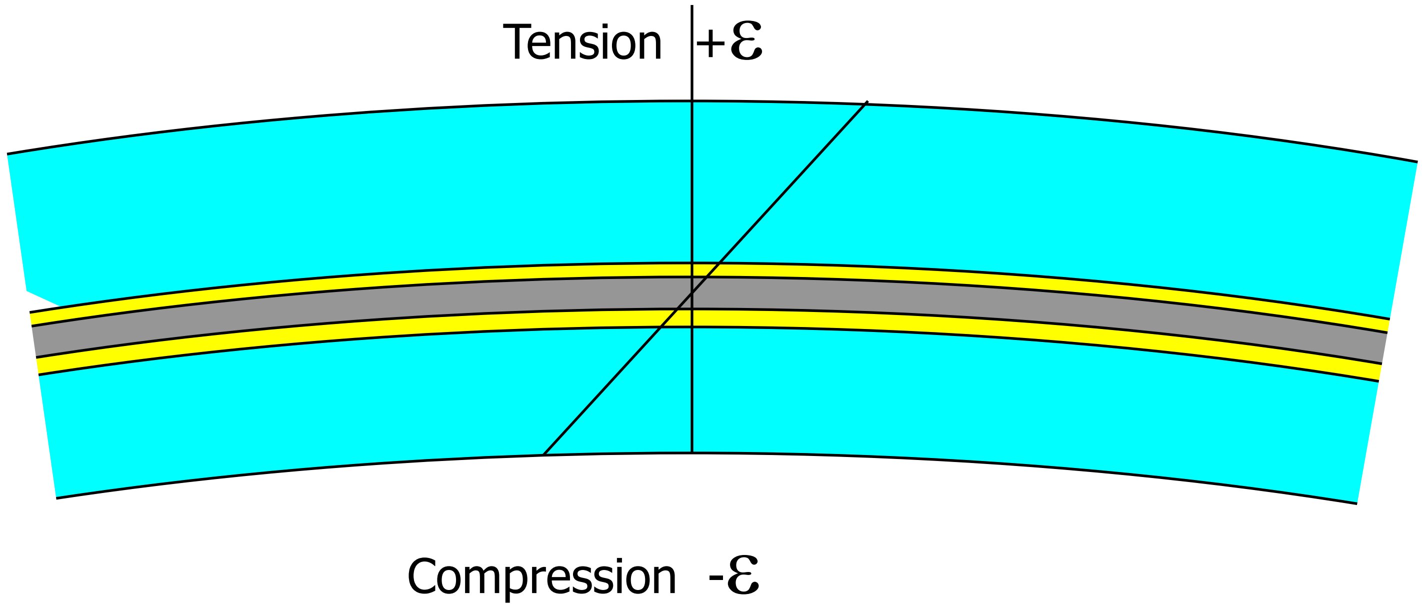
Increasing Moment-Deflection Design Space



Guiding Hard-Launched Rounds… The Epiphany!

Increasing Moment-Deflection Design Space

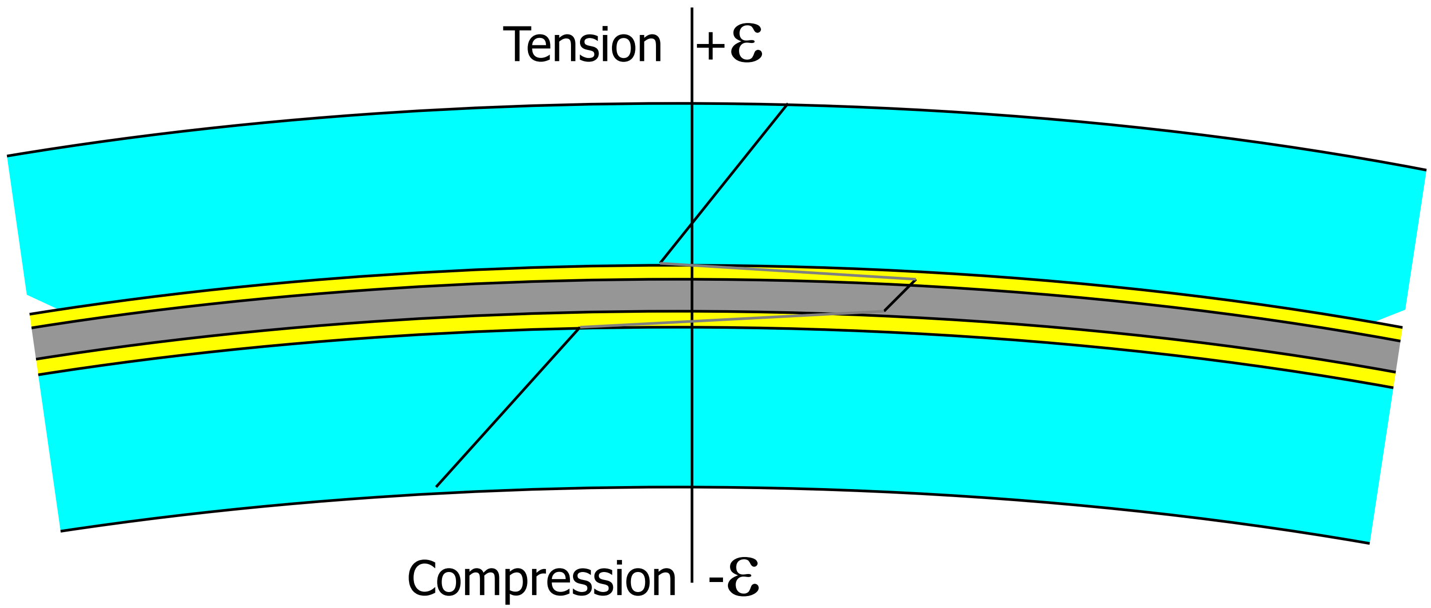
The Limiter: Strain on Convex Face



Guiding Hard-Launched Rounds… The Epiphany!

Increasing Moment-Deflection Design Space

Improvement: Precompression via CTE mismatch cure

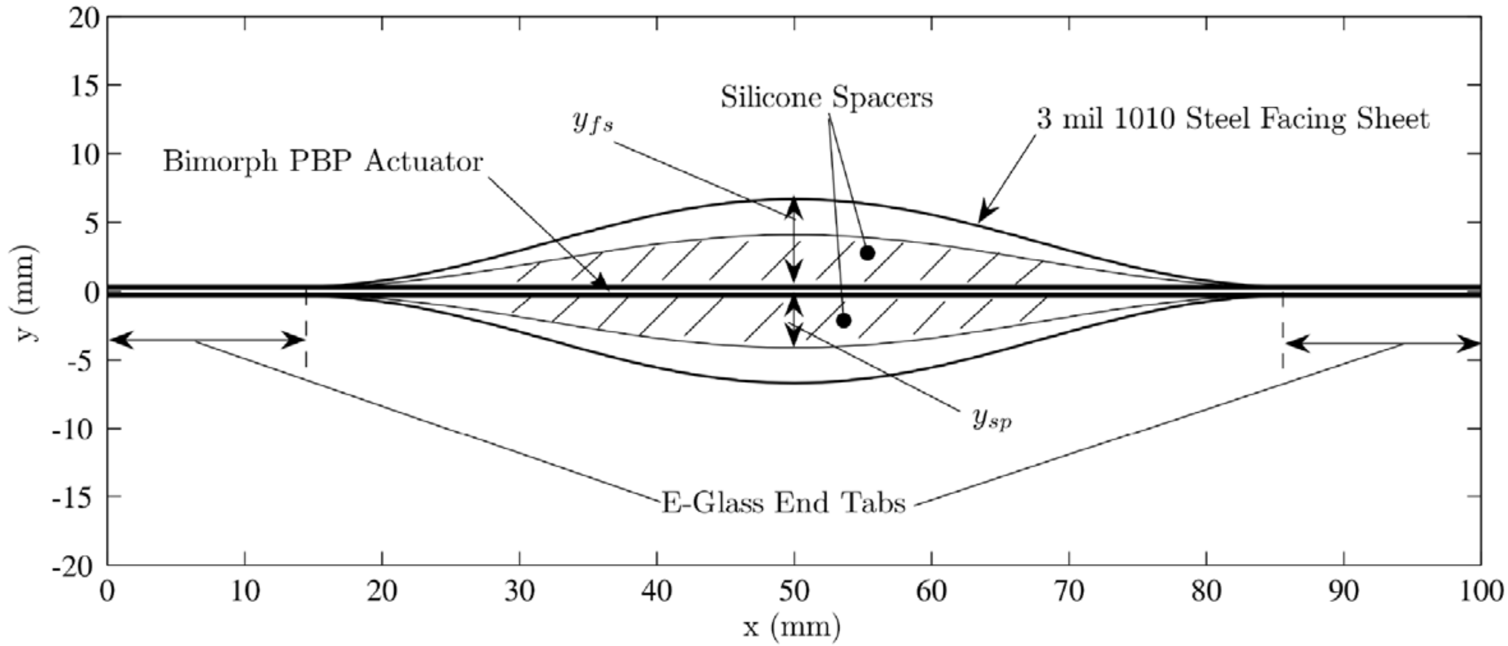


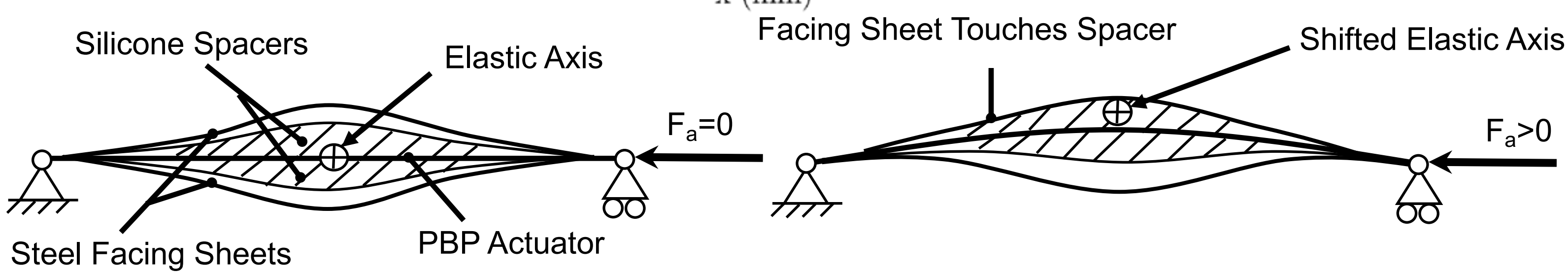
Guiding Hard-Launched Rounds… The Epiphany!

- Require bump-stops to prevent overrotation
- Depoling/fracture boundaries limit deflection
- High in-plane tensile stresses on convex face leads to premature depoling under cyclical loading
- Assembly and tuning is very tricky

Guiding Hard-Launched Rounds… The Epiphany!

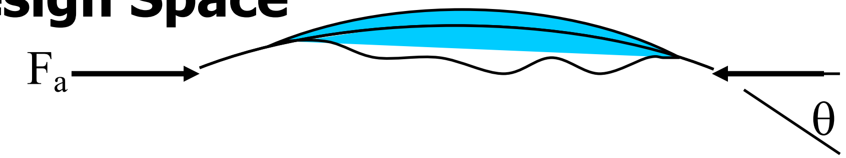
Increasing Moment-Deflection Design Space



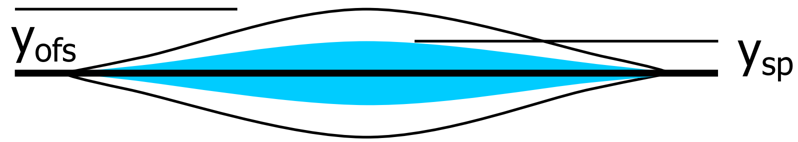


Guiding Hard-Launched Rounds… The Epiphany!

Increasing Moment-Deflection Design Space



Facing sheet engagement theories



- First order model: *assumption: $y_{sp} = y_{fs}$*

$$\tan\theta = \frac{4}{L_{sp}}(y_{0fs} - y_{sp}) \tag{5}$$

- Higher Fidelity model:

assumption: $L_{sp} = L_{fs}$

$$L_{fs} = \int_0^{L_{sp}} \sqrt{1 + \left(\frac{dy_{fs}(x)}{dx}\right)^2} dx = \int_0^{L_{sp}} \sqrt{1 + \left(\frac{y_{0fs}\pi}{L_{sp}} \sin\left(\frac{2\pi x}{L_{sp}}\right)\right)^2} dx \tag{6}$$

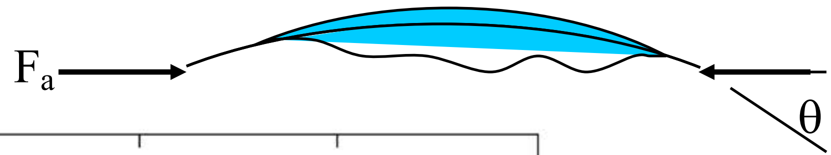
$$L_{fs} = \int_0^{L_{sp}} \sqrt{1 + \left(\frac{dy_{sp}(x)}{dx}\right)^2} dx = \int_0^{L_{sp}} \sqrt{1 + \left(\frac{y_{0sp}\pi}{L_{sp}} \sin\left(\frac{2\pi x}{L_{sp}}\right) + \left(1 - \frac{2x}{L_{sp}}\right)\tan\theta\right)^2} dx \tag{8}$$

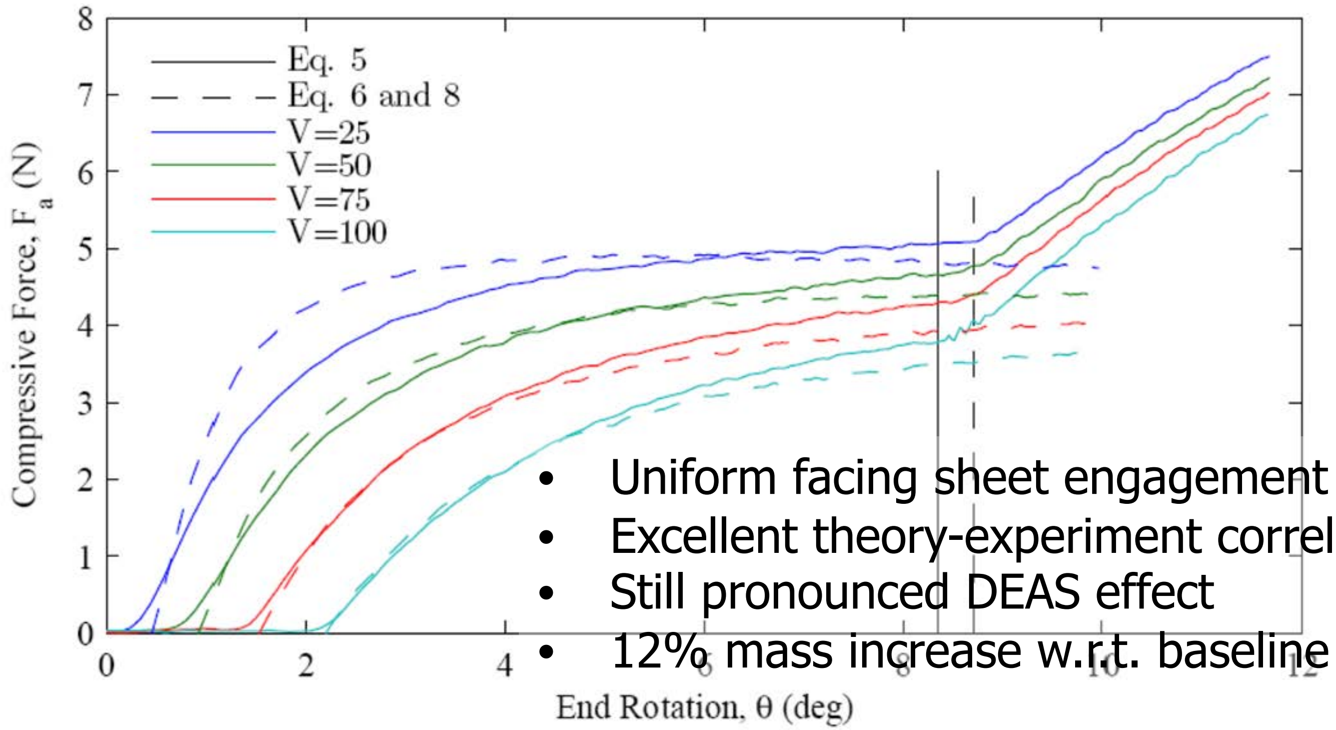
Equating (6) and (8) allows solution for θ

Guiding Hard-Launched Rounds… The Epiphany!

Increasing Moment-Deflection Design Space

- 2mm wide, 69µm graphite-epoxy facing strips
- 1.7mm thick silicone spacer
- Spacer, y_{sp}=1.75mm





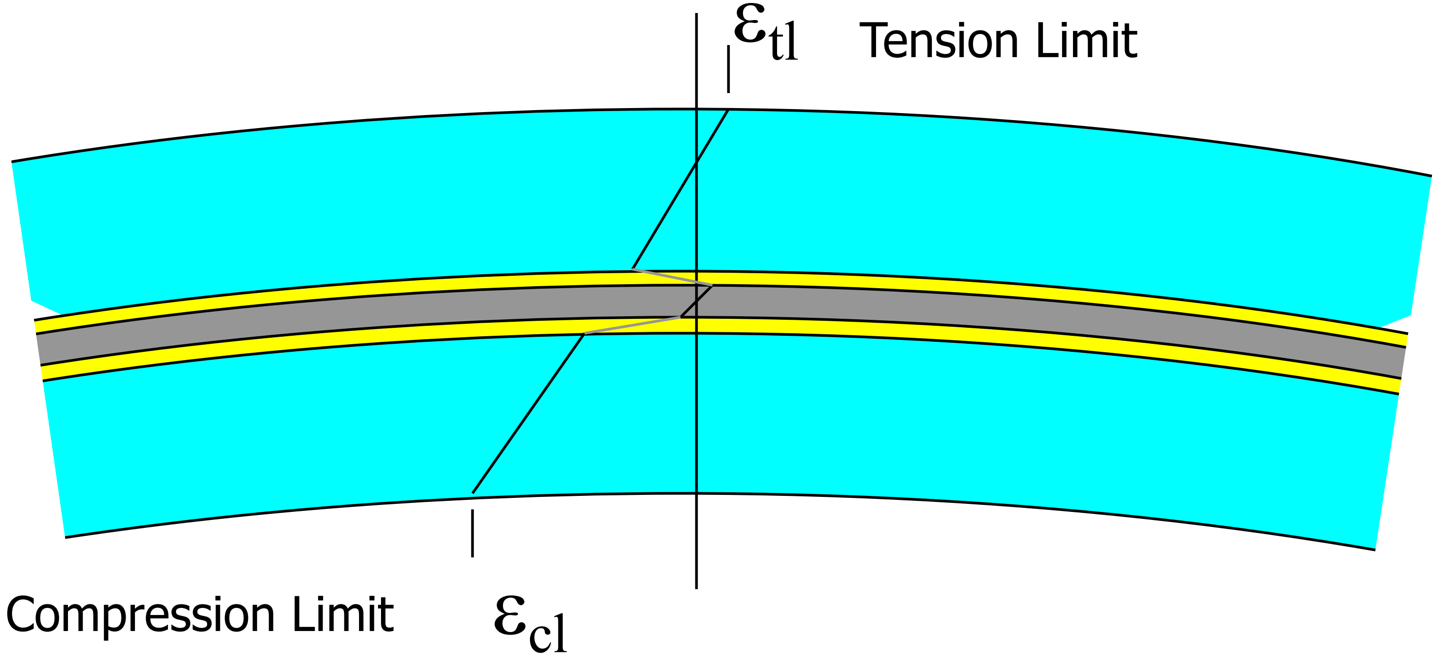
- Uniform facing sheet engagement
- Excellent theory-experiment correlation
- Still pronounced DEAS effect
- 12% mass increase w.r.t. baseline PBP element

$$\sqrt{\frac{F_a}{Db}}\int_0^{\frac{L}{2}} ds = \frac{L}{2}\sqrt{\frac{F_a}{Db}} = \int_0^{\frac{\pi}{2}} \frac{\sin\left(\frac{\theta}{2}\right)\cos\xi}{\left(\sqrt{\sin^2\left(\frac{\theta}{2}\right)\cos^2\xi + \frac{\kappa^2 Db}{4F_a}}\right)\left(\sqrt{1-\sin^2\left(\frac{\theta}{2}\right)\sin^2\xi}\right)} d\xi, \qquad (10)$$

Guiding Hard-Launched Rounds… The Epiphany!

Increasing Moment-Deflection Design Space

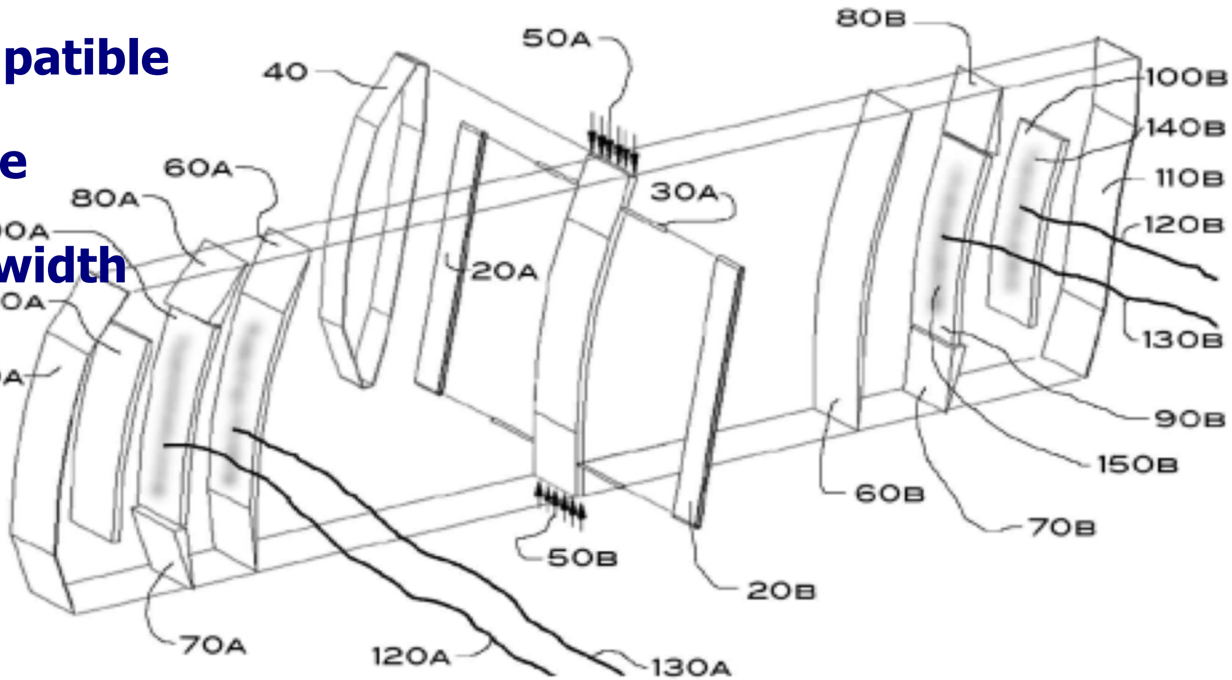
Proper Dynamic Elastic Axis Shifting DEAS Design:



- Tension limit reached on convex face
- Compression limit reached on concave face
- Bond shear stresses below limit

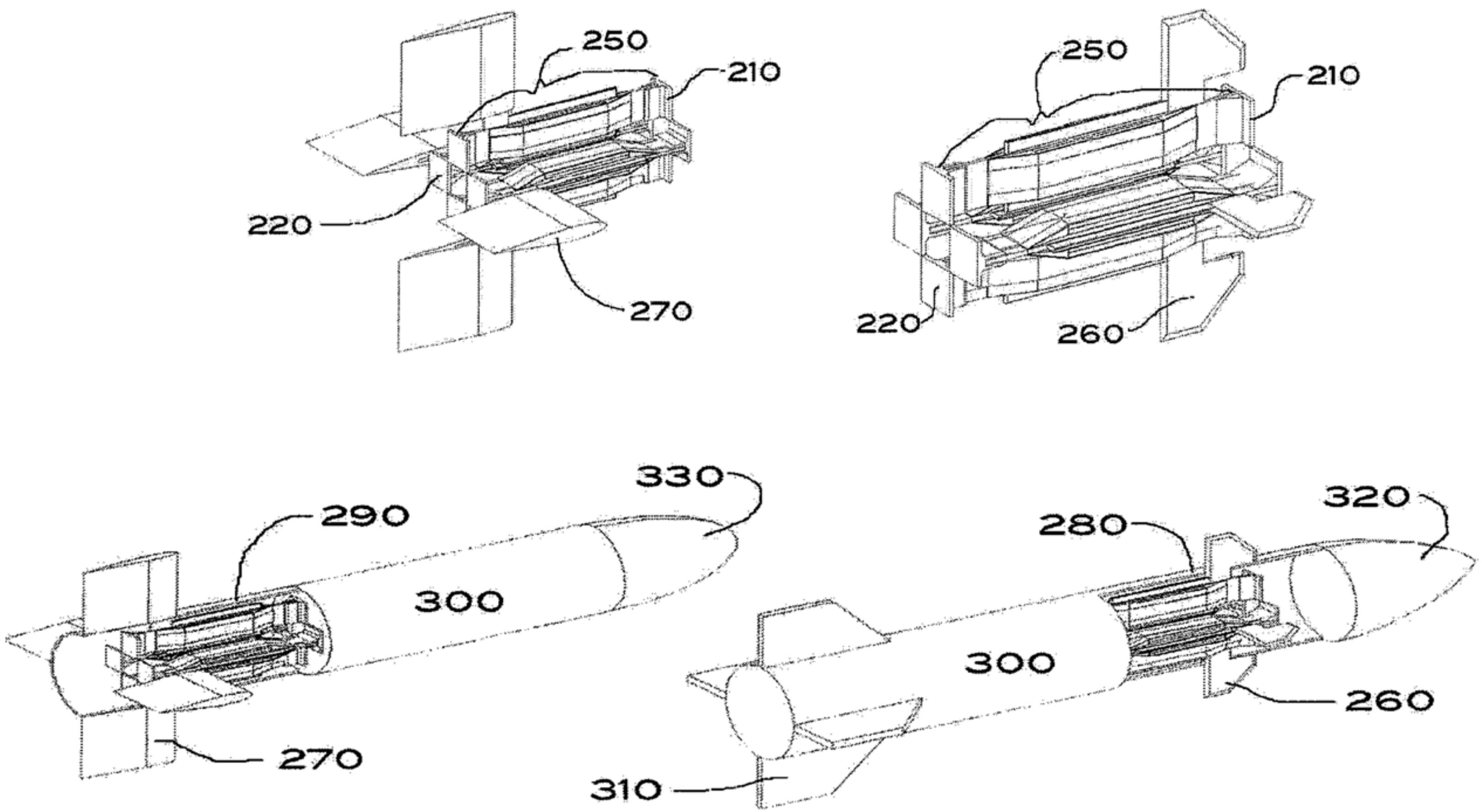
PBP Actuators: The FCS Solution

- Fraction of the weight, size & power consumption of conventional Actuators (i.e. much smaller actuator bays)
- 300+% deflection increases with full force/moment capabilities
- Mass production compatible
- ±0.01 deg. trimmable
- Extremely high bandwidth
- Lower g-sensitivity
- Very low cost



PBP Actuators: Assemblies

Assembled Hard-Launch Capable Actuator FCS Units:



Unlimited Distribution

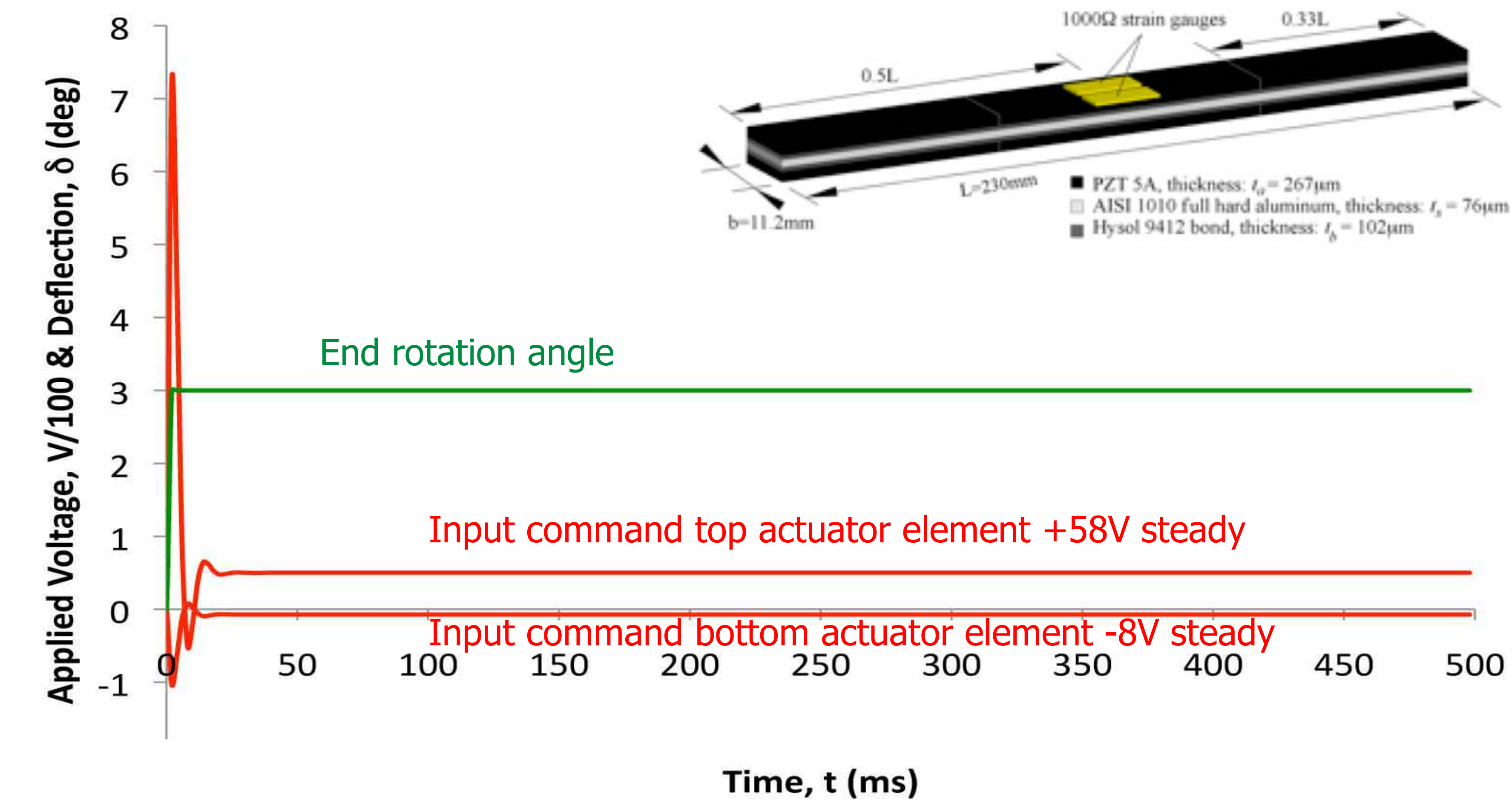
Unclassified

US Pat issued March 2011 *Multiple Licensees*

PBP Actuators: Fastest around…

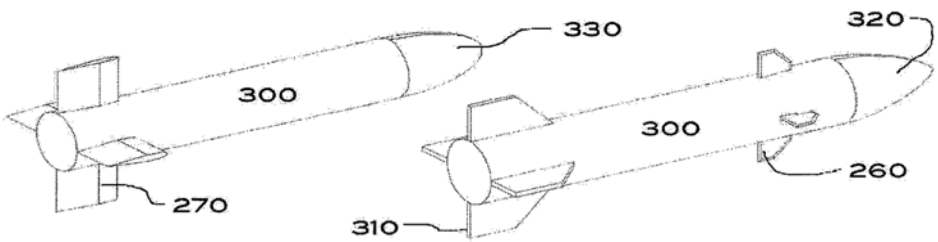
Best performance in the adaptive structures industry:

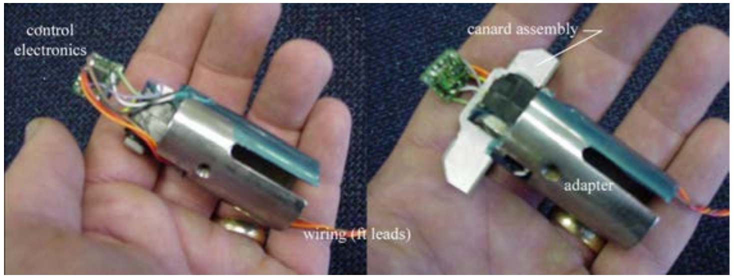
- **1kHz equivalent bandwidth**
- **Driving 0.40/.50 cal Mach 4.5 canards**



PBP Actuators: Munitions Comparisons

Smaller, Lighter, Less Expensive, More Rugged…





	Conventional Electromagnetic FCS	Adaptive/PBP FCS
Volume	14cc	5.1cc
Mass	69g	4.2g
Peak Power	148W	2.6W
Deadband/Slop	$\pm 0.38^\circ$	$\pm 0.002^\circ$
Bandwidth	22 Hz	189Hz
Acquisition Cost (100,000 shipsets)	$187 ea.	$12.30

Unclassified Unlimited Distribution

New Enabled Missions:

Conventional Air-to-Air Missile Replacement

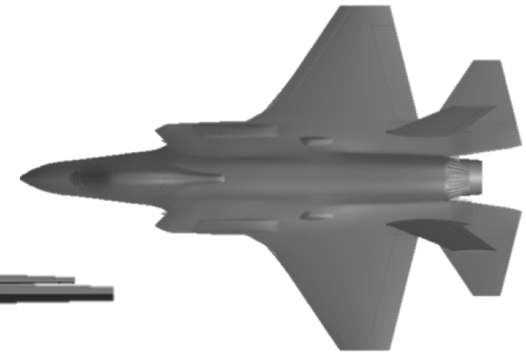
-Airframe Shrinkage

-Force Multiplication

-Counter-Missile

-Self Defense

-LO Enhancement



New Enabled Missions:

Enhanced Aerial Gunnery Capabilities

-30mm GAU-8/PGU-14 E_{Impact} ↔ 25mm MASS Guided Hard-Launch Munition

-25mm GAU-22/PGU-47 E_{Impact} ↔ 20mm MASS Guided Hard-Launch Munition

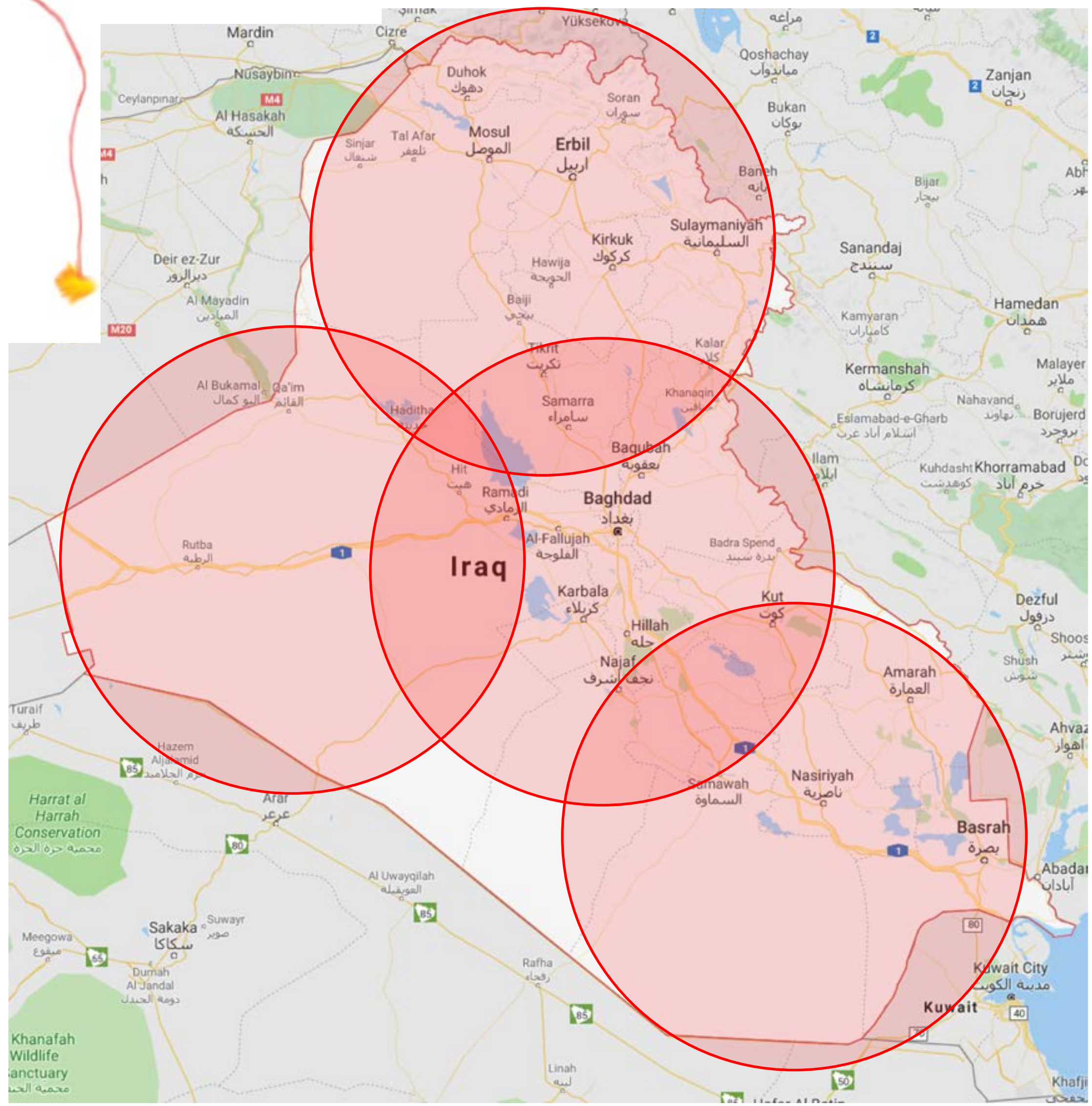
-20mm M61A1/PGU28 E_{Impact} ↔ 16mm MASS Guided Hard-Launch Munition

New Enabled Missions:

FAC-130…

Air-to-Air…

Indirect Fire Support



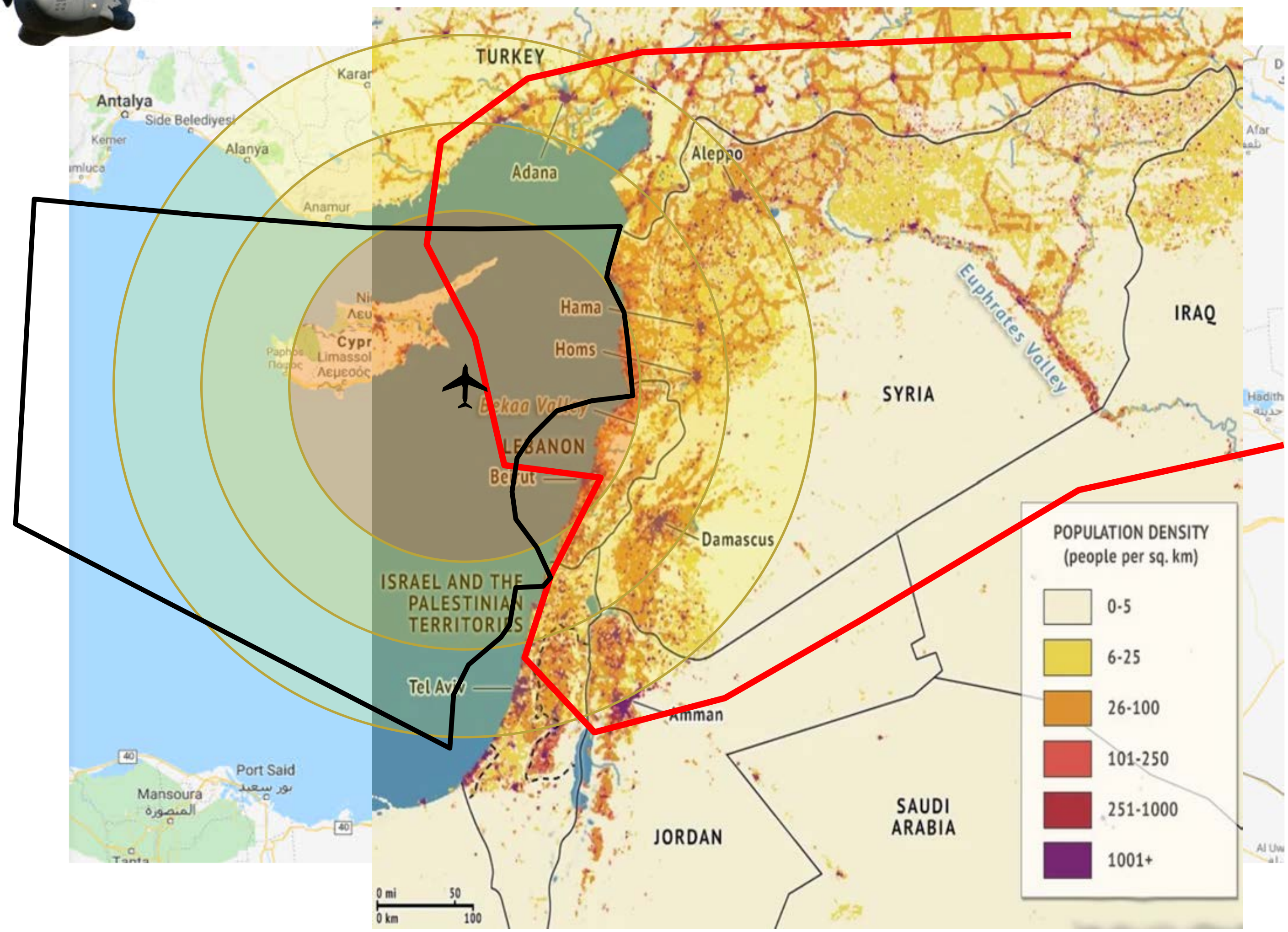
New Enabled Missions:

FAC-17

Indirect Fire Support…

Air-to-Air &

Self-defense



Questions?

A Structured Approach to Fuze Technology Refresh

Vince Matrisciano
Research & Development Program Manager
Joint Program Executive Office Armaments & Ammunition

Distribution A: Approved for public release, 22 April 2019, PAO # 325-19

Today's Challenge

- Fuzing is a niche industry and the volume is relatively small.
- Fuze designs, particularly those with electronics, are typically obsolete before they are fielded.
- Because of shelf life requirements and the challenge of requalifying designs, fuze designs are relatively static for up to 20 years or more.
- DoD is no longer the driver for the supply of components. For electronics, we are far behind the buying power of companies like Apple, Ford, GM, Nintendo, etc.
- Rigid acquisition processes discourage design changes.

Today's Opportunity

- Acquire fuzes so that changes in technology and manufacturing methods can be quickly, easily and proactively incorporated into ongoing production.
  - Systematically identify and replace aging technology.
  - Exploit new technology advances sooner.
  - Pre-plan qualification activity.
  - React more quickly to threat based requirements.

Adopt Industry Approach of
Planning the Next Version while Fielding the Current Version

Fuze Technology Insertion Challenges

- Do we need a formal requirements change?
- Will the Nomenclature change and affect Logistics?
- How do we proactively identify obsolescence?
- Is the item a continuous buy or batch buy?
- How do we connect the technology community with the acquisition community and the funding community?
- How do we pay for the cost of requalifying?
- Who's the decision maker?

More Challenges…

- Re-qualification can be costly and time consuming. Pre-planning can streamline and reduce the scope of re-qualification.
- Gov’t engineers need to be much more aware of commercial electronic development as it relates to fuzes, so that stronger consideration is given to adapt commercial components.
- More active management is required to identify and prioritize specific technology insertions for each refresh cycle, ensuring all stakeholders are aligned.
- We also need to formally address (and waive as appropriate) certain requirements, such as the “20 year shelf life” requirement.

The Good News

- New production contracts (typically every 5 years) are a built in opportunity to update designs and specs to insert new technology.
- Many fuzes are modular – the fuze can be updated without changing the munition.
- There is significant ongoing fuze design activity: Gov't S&T, Joint Fuze Technology Program (JFTP), IRAD, etc.
- There is a lot of R&D work in modelling, which will speed the pace of development.
- The DoD Fuze IPT provides a great structure to align stakeholders and execute a strategy!

The New Approach

- **Annual cycle** - identify and prioritize technology refresh opportunities every year
- **Pre-planned upgrades** - while we are producing the current version
- **Coordinated approach** - Gov't technology developers, Gov't PMs, Gov't requirements developers, Industry developers and producers.
- **Flexible** - ability to insert "out-of-cycle" priority changes

Go Forward Plan

Leverage existing DoD Fuze IPT and NAC Fuze Advisory Panel:

- Meet at least once per year to focus on refresh strategy.
- Gain a common understanding of gaps and needs.
- Coordinate technology development efforts.
- Identify solid transition opportunities.
- Establish an acquisition approach to accept the new technology.
- Coordinate IP strategies.
- Track progress on development and transition.

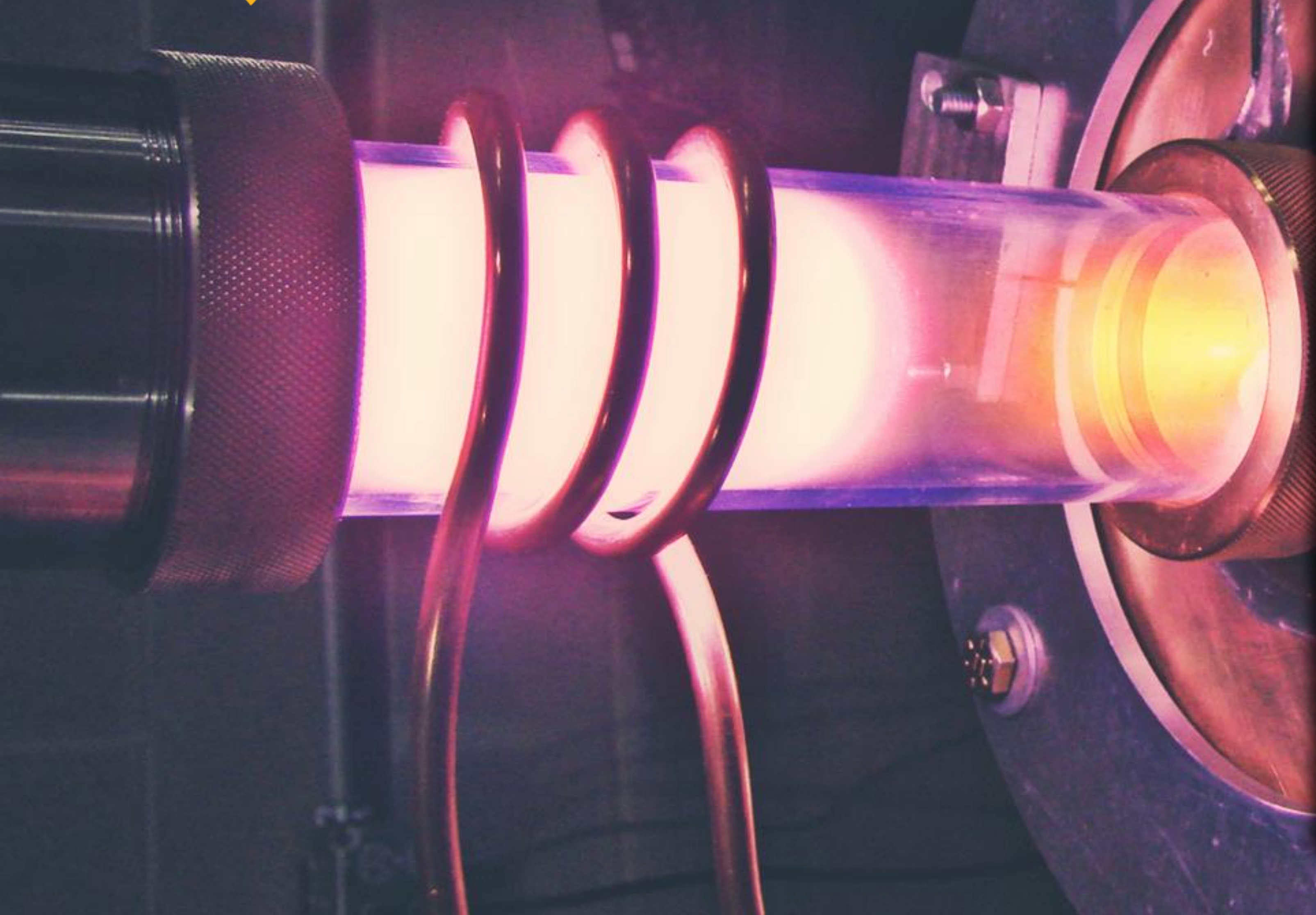
If you want to be involved…

Contact me!

THANK YOU

PHOENIX

TRANSFORMING NUCLEAR TECHNOLOGY



High Quality, High Throughput Neutron Radiography Using Accelerator Based Neutron Generators

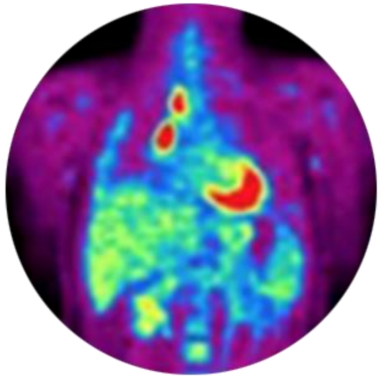
NDIA Fuze Conference

May 15th, 2019

Brad Bloomquist
Director of Business Development
Phoenix, LLC

Company Snapshot

- Phoenix delivers ion source and accelerator products and systems to several different markets
- Commercial systems have been fielded and are operating to specification:
  - Neutron radiography, neutron detector calibration, semiconductor ion implantation, medical isotope production
- **Eight new systems** are in process this year for commercial and government customers
  - Same applications as above plus radiation effects testing, fast neutron radiography IED detection, explosives detection, and nuclear fuel scanning



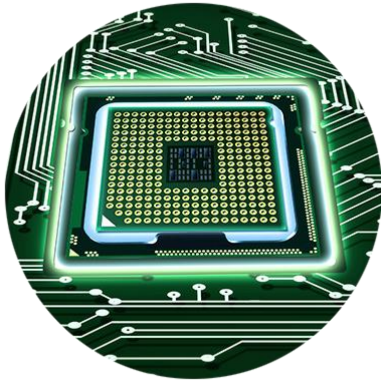
Medical

Non-Destructive Test

Defense

Aerospace

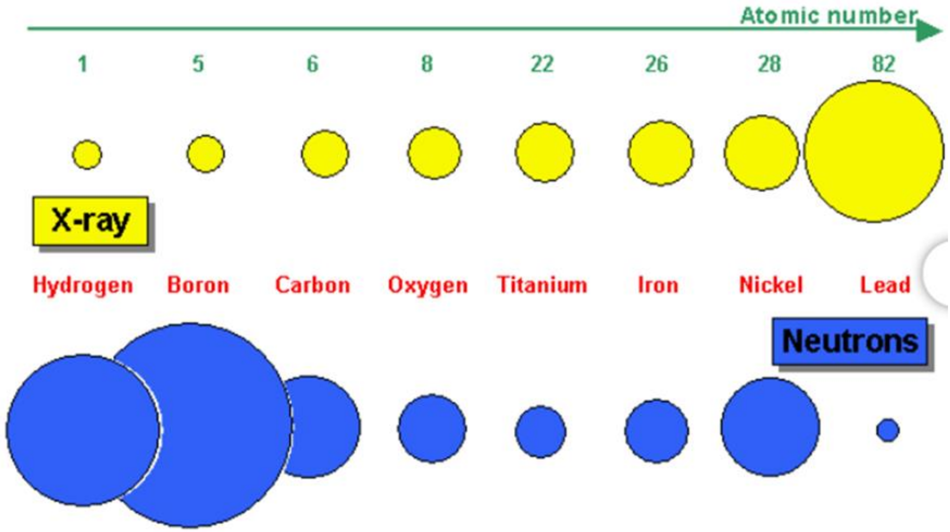
Nuclear QC & Calibration

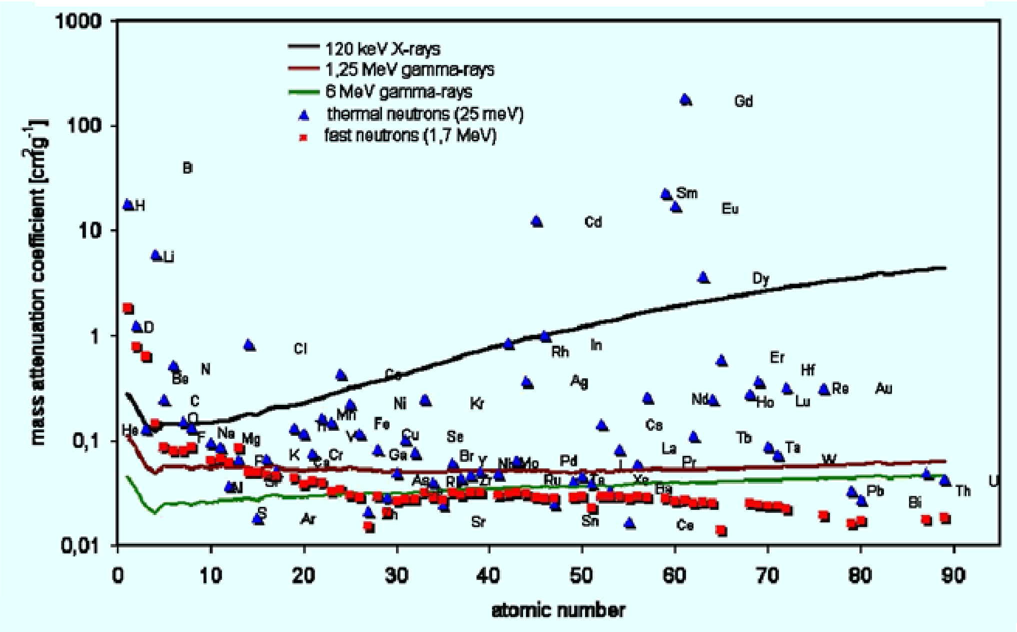


Semiconductor

Neutron Radiography (N-ray)

- Non-destructive imaging technique complementary to X-ray
- Neutrons interact with atomic nucleus not electron cloud
  - Attenuation determined by elemental composition not material density
  - Certain materials have very high neutron attenuation
- What is the technical value of n-ray?
  - Provides unique material-to-material and material-to-background contrast resulting in unique information about a part
  - Particularly valuable when trying to view features inside high density (metal) containment
  - Allows detection of certain defects (cracks, voids, gaps, foreign material, assembly errors, etc) that cannot be detected with any other non-destructive method

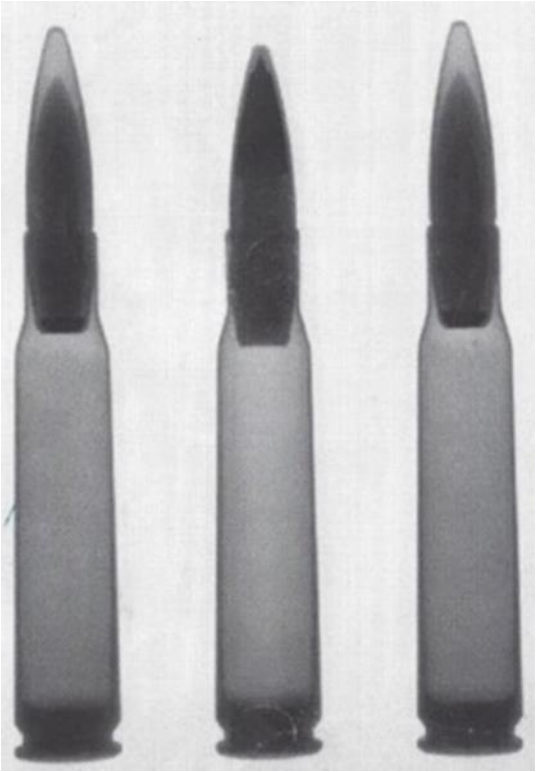




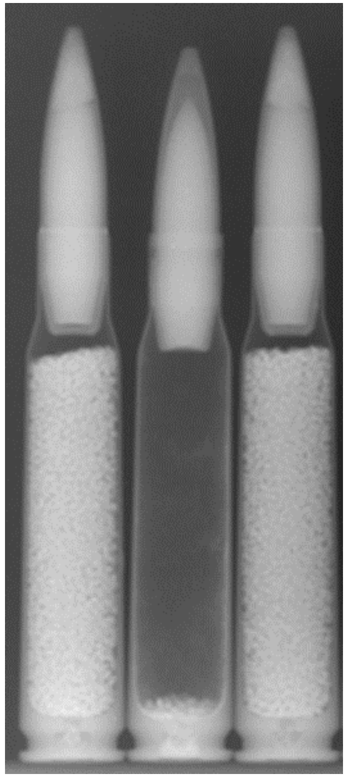
Why we do neutron radiography: The mass attenuation coefficient of elements

N-Ray Use Examples

X-Ray Radiograph (X-ray)



Neutron Radiograph (N-ray)



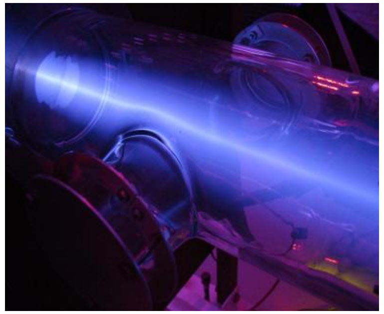
- X-rays and other existing nondestructive testing (NDT) methods have difficulty with certain known defects in these products:
  - Turbine blades
  - Cartridge actuated devices
  - Propellant actuated devices
  - Explosive transfer line
  - Frangible joints
  - Mild detonating fuse
  - Initiators
  - Electronic bridge wire detonators
  - Explosive bolts
  - Safe and arm switches
  - Warheads or projectiles with fragmenting shape charges
  - 0.50Cal/30MM Tracer and Incendiary Cartridges
  - Small and Medium Caliber Ammunition
  - 105-155mm artillery shells
  - Ceramic Body Armor
  - Internal liners or sealants
  - Liquid-Filled Cells (e.g., certain batteries)
- Many of these defect detection challenges could be solved with Phoenix neutron radiography systems
- Industry uses majority of existing n-ray capacity to examine turbine blades, energetic components and other high cost of failure parts

Available Neutron Sources

Neutron Tubes & Isotopic

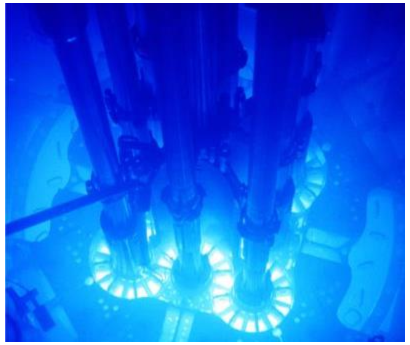
~$100ks

Industrial Accelerators



~MM-$10MMs

Nuclear Test Reactors and Large



~$100MMs to $1B+

10^6 10^7 10^8 10^9 | 10^{10} 10^{11} 10^{12} 10^{13} | 10^{14} 10^{15} 10^{16} 10^{17}

Neutrons/second

Isotope decay or low yield fusion produces neutrons

Table top sized

Limited Intensity

Limited Applications

High yield fusion or scattering reactions produce neutrons

Room sized

Moderate - high Intensity

Simple regulations

Fission of uranium produces neutrons

High Intensity

Safety to public & personnel drives high regulatory burden & operating cost

Produces spent nuclear fuel and other highly hazardous & costly wastes

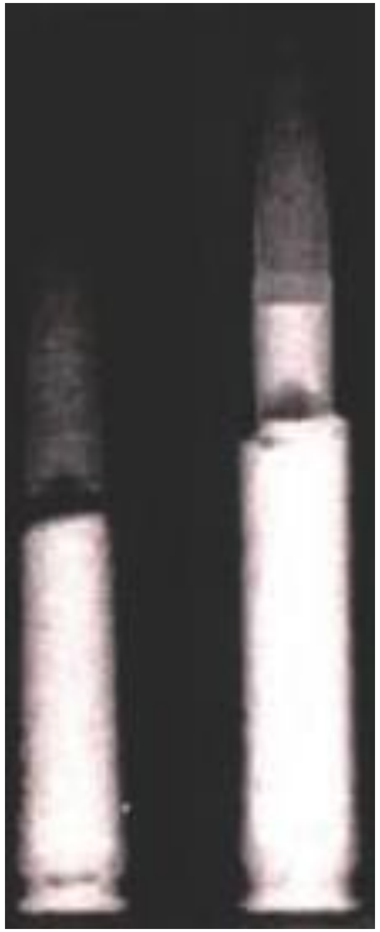
Addressing the Challenge…Today

- Phoenix has developed neutron radiography technology in collaboration with the Army over the last 10 years:
  - First prototype delivered to Picatinny Arsenal in 2013
  - Low Volume Prototype has been operating at Phoenix facility for past year
  - Excellent image quality has been demonstrated on the prototype system
  - Low Volume Pilot Unit shipping to Picatinny Arsenal in coming months

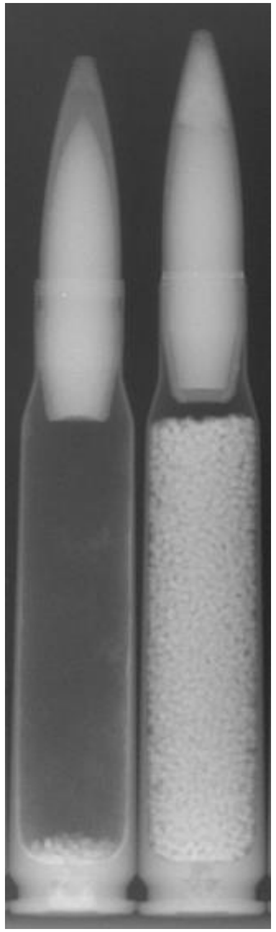

2013


2017

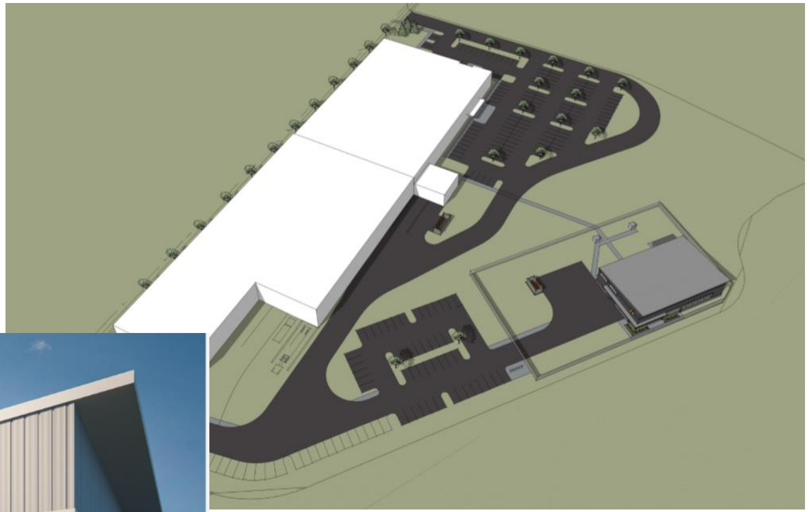
2013



2017



Phoenix Neutron Radiography Facility

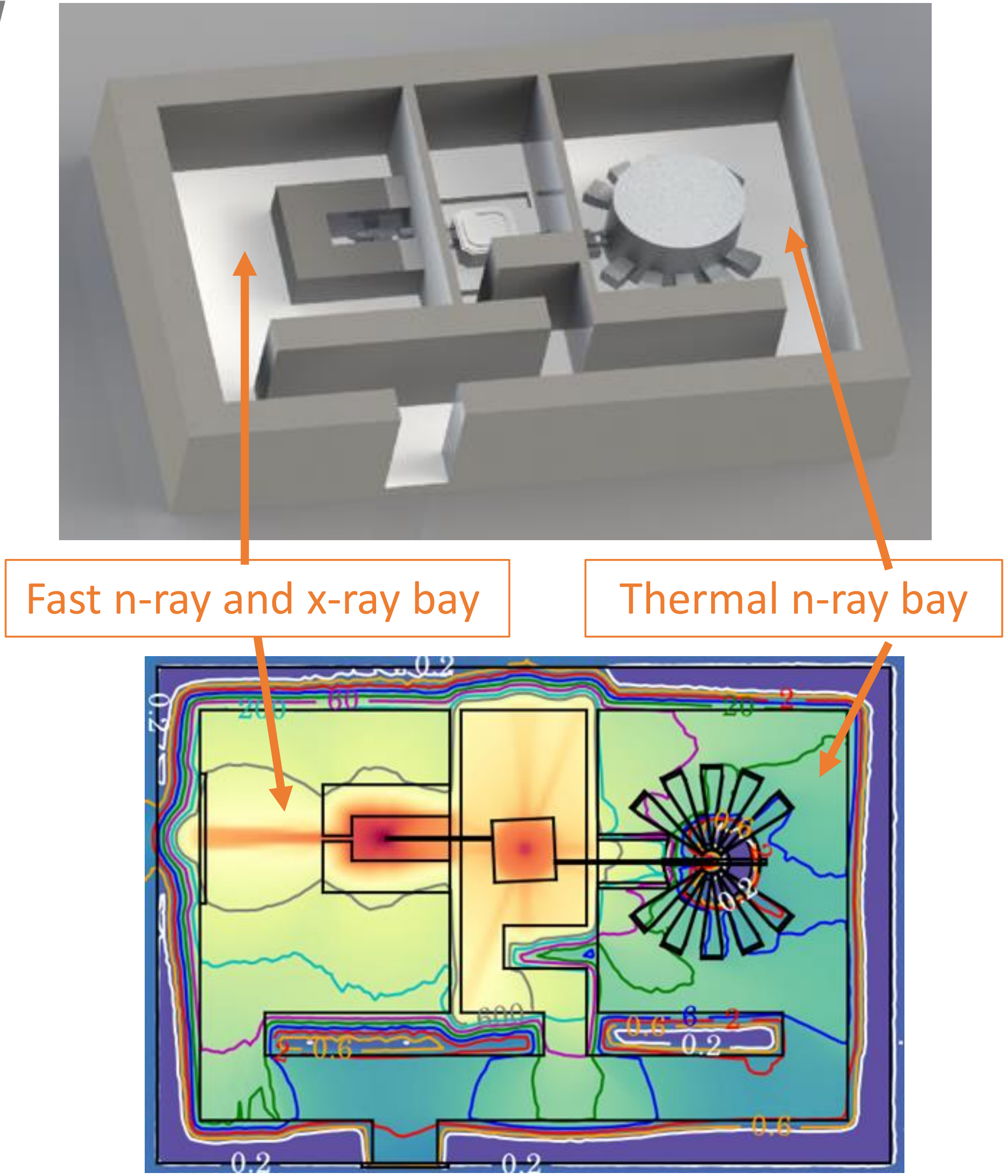


- Phoenix is investing to build a one-of-a-kind facility…the Phoenix Neutron Imaging Center (PNIC)
- First operation fall 2019

- ATF Compliant & Permitted
- Compliant with DoD Ammunition & Explosives Safety and Security Manuals (4145.26 & 5100.76)
- Aerospace & defense quality programs for process and personnel (ISO9001, AS9100, NAS410, etc)
- On contract with Army & Navy to demonstrate high quality, high throughput thermal n-ray and fast n-ray this fall

Facility Detail

- System creates neutrons through a different reaction than previous systems
- Higher neutron yield system
  - Higher energy … produces more intense ion beam
  - Plus advanced target, moderator & collimator designs
  - No tritium, uranium or other radioactive fuel
- Results in 100X higher thermal flux and higher neutron energy
  - 10 thermal beam ports reduce effective imaging time to minutes or seconds, depending on specimen size, materials and desired image quality
  - Fast neutron capability can penetrate components up to ~0.5m thick
  - End result is major throughput and versatility enhancements
- X-ray capability allows on-stop-shop for radiographic inspection



Thermal N-Ray Parameters

L/D = length of collimator to diameter of aperture…Ensures high resolution

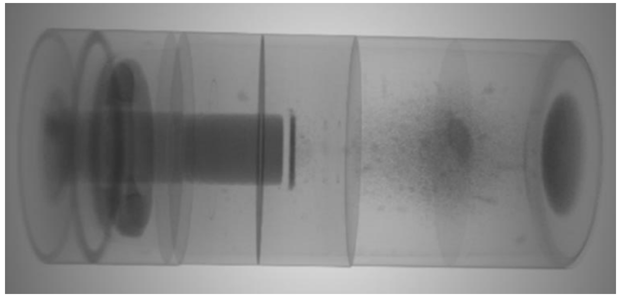
Flux = number of neutrons / area…multiple imaging ports multiplies usable flux

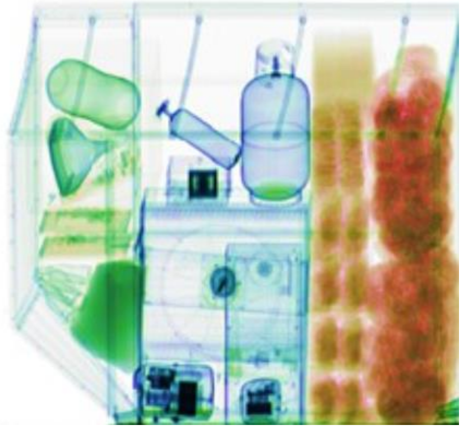
N:gamma ratio = want neutrons not gammas exposing film…important for ensuring high contrast

Cd ratio = fast to thermal neutrons…important for ensuring high contrast

Parameter	Nuclear Reactor (current baseline)	Phoenix DD System	Phoenix High Yield System
Regulatory Burden	NRC Regulated	Minimal	Minimal
L/D Ratio	**105**	**35**	**70 - 100**
Thermal Neutron Flux @ Image Plane ($n/cm^2/s$)	**3.00E+06**	1.12E+04	**3.20E+05**
Neutron : Gamma Ratio	>1E6	MEDIUM	>1E6
Cadmium Ratio	>5	<2	>4
Time per Film Exposure (minutes)	5.6	1488.1	52.1
Time per CR Exposure (minutes)	3.8	1011.9	35.4
Annual Film Capacity (# Exposures)	**>20,000**	>3,000	**>25,000**
Annual CR Capacity (# Exposures)	n/a	>4,500	>35,000

Fast Neutron Imaging



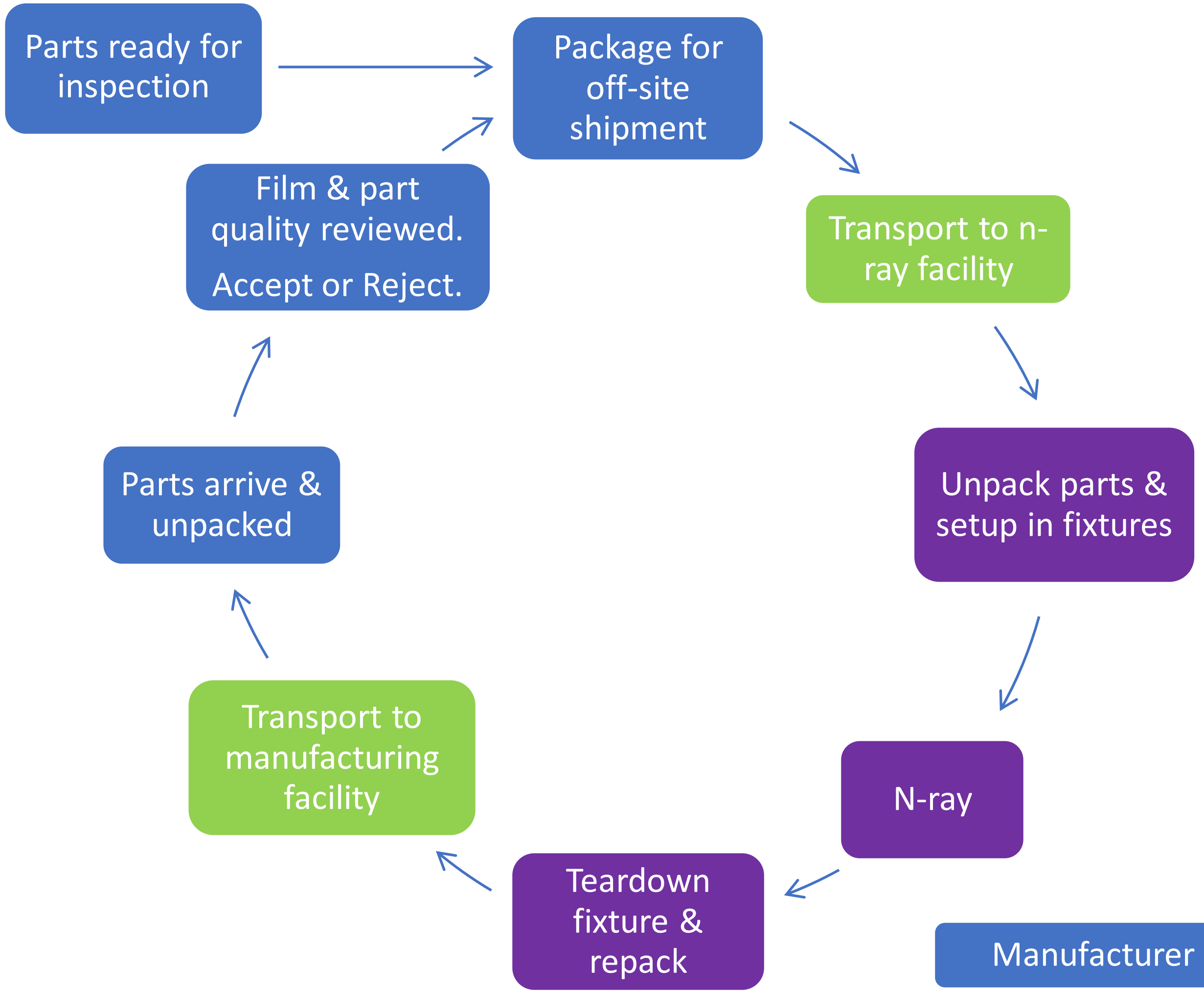


- Similar to high energy X-ray, ‘fast’ neutrons are high energy neutrons that can penetrate thicker & denser items
- Large caliber munitions, missiles and solid rocket motors
  - Need high penetration through thick metal cladding, warheads or fuel to view internal parts
- Bulk Cargo
  - Ports of entry, airport cargo, railway, military base protection
  - Can detect explosives, drugs and contraband with image and spectral analysis

Operation & Regulatory

- Simple operations…a single user interface, controlled by a single trained operator
- Common industrial hazards…flammable & compressed gasses, high voltages, ionizing radiation, pressure vessels
- No credible major accident scenarios…no nuclear meltdown, fission product release, etc.
- System has sensors and interlocks to protect machine and people…system shuts down in milliseconds
- Simple regulatory framework…no Nuclear Regulatory Commission license, state license/permit as with industrial X-ray units
- Common waste streams…no spent nuclear fuel or other wastes without disposal paths

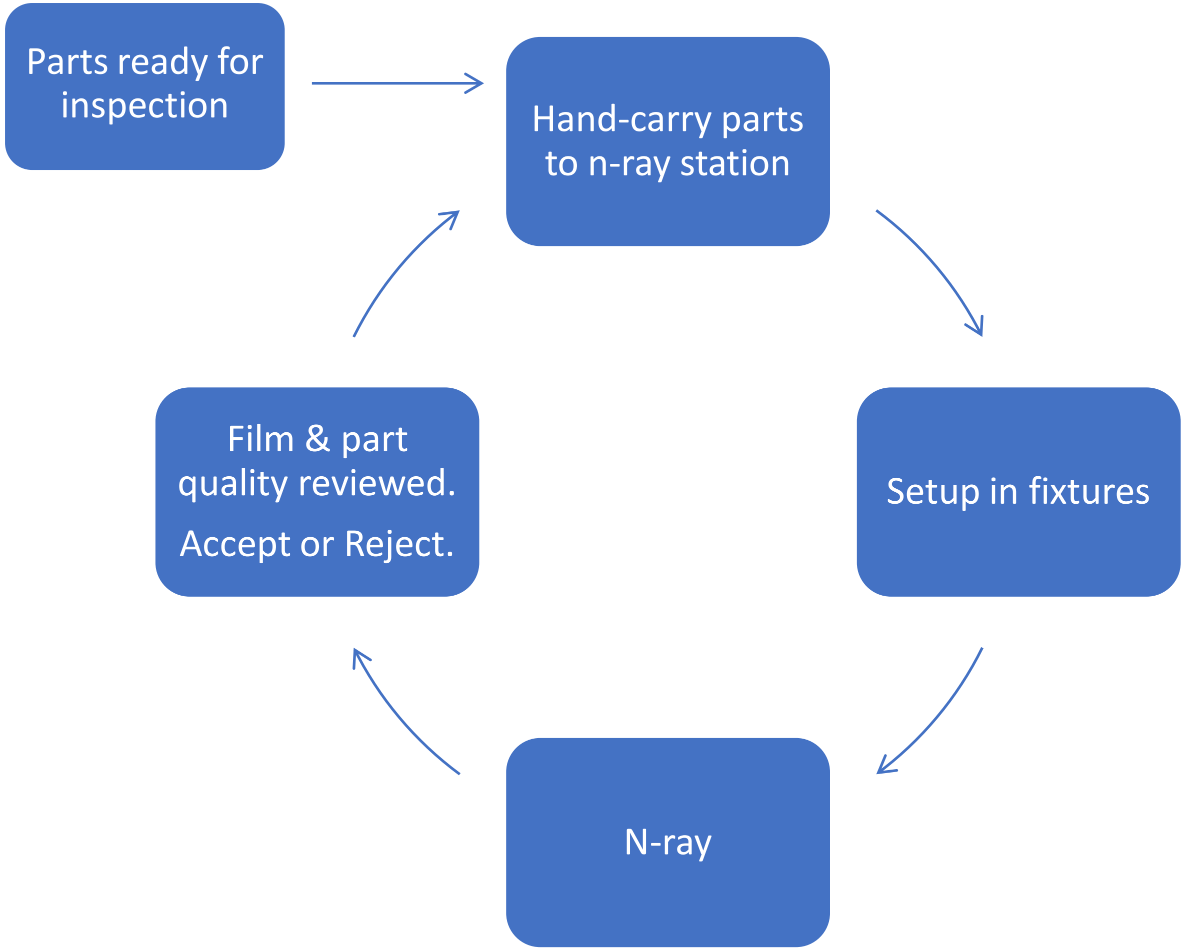
Reactor Based Radiography Cycle



- 1-2 week <u>typical</u> duration + risks (weather, shipping deadlines, work loads)
- Multiple changes in custody and potential part traceability points-of-failure
- Multiple contracts, forms, travelers, etc
- Increasing costs in transport and n-ray service
- Export control, ITAR and IP concerns
- Little to no process flexibility

Manufacturer possession | Transporter possession | N-ray Reactor possession

On-Site Accelerator Radiography Cycle



- Minutes - hours duration + no schedule risk
- No changes in custody or traceability issues
- No recurring contracts
- Cost reductions
- High process flexibility…in-process n-ray now a possibility

Manufacturer possession

Conclusions

- Technology has leapt forward and current generation systems have achieved near reactor quality images
- Next generation system available in fall 2019 and expected to match or exceed reactor image quality while greatly improving throughput and maintaining low regulatory burden of previous systems
- PNIC facility offers a short-term remedy to a currently fragile supply chain for defense critical items
- To be efficient, inspections need to be deployed at the site of production, which Phoenix systems now allow
  - 100% new product inspection or lot sampling
  - Service life monitoring and extensions
  - Failure analysis
  - R&D and prototype support
- Phoenix technology allows the reinvigoration of valuable NDT technique that has gone dormant due to decades of decline in reactor access
- Bring us your inspection challenges…actively seeking industry partners for defect detection or sample imaging studies…energetics, munitions, fusing, additive manufacturing are full of potential n-ray applications

PNIC Groundbreaking Ceremony October 30, 2018

Phoenix

Transforming Nuclear Technology

Madison, WI

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Indian Head EOD Technology Division

Survivability and Reliability of Silicon MEMS Components

Presented to:

NDIA 2019 Fuze Conference
Presentation 21868

Presented by:

Caitlyn May
Mechanical Engineer

- 15 May 2019 -

Capt. Scott H. Kraft, USN
Commanding Officer

Mr. Ashley G. Johnson, SES
Technical Director

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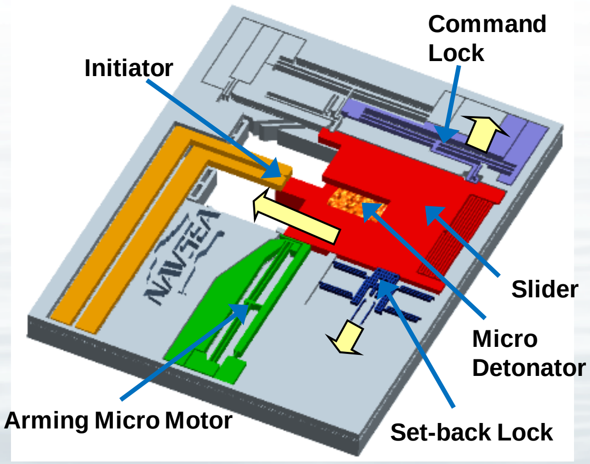
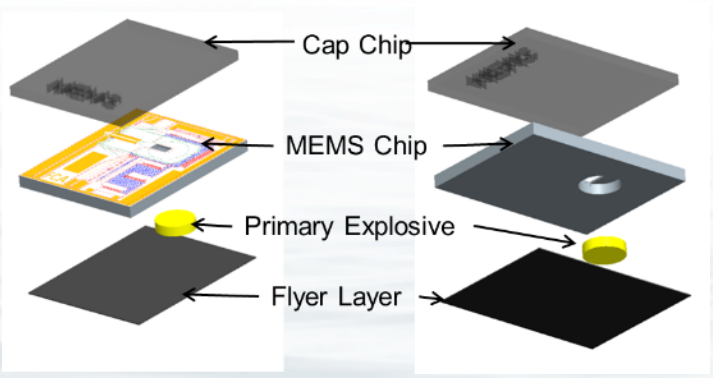
MEMS Safe and Arm

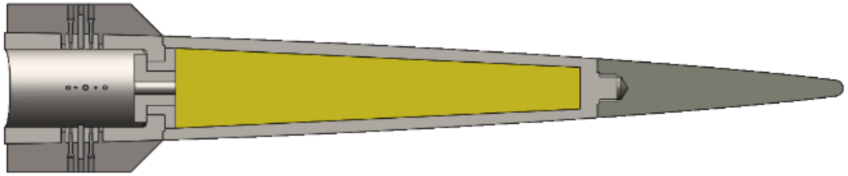
- Micro-electro Mechanical System (MEMS) Safe and Arm Devices (S&A) offer the potential for small volume, low cost, and low energy consumption.
- NSWC IHEODTD has nearly two decades of silicon/silicon on insulator (SOI) MEMS design, fabrication, and packaging experience.
- Safety locks: integrated mechanical structures used for command actuated locking architectures.
- Arming: design and fabrication of environmentally derived and command architectures.
- All non-explosive components fabricated on SOI wafers using established semi-conductor processes.



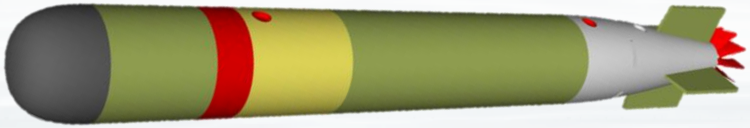


MEMS Fuzing Applications

Gun Launched Projectiles



Underwater Systems



Mortars

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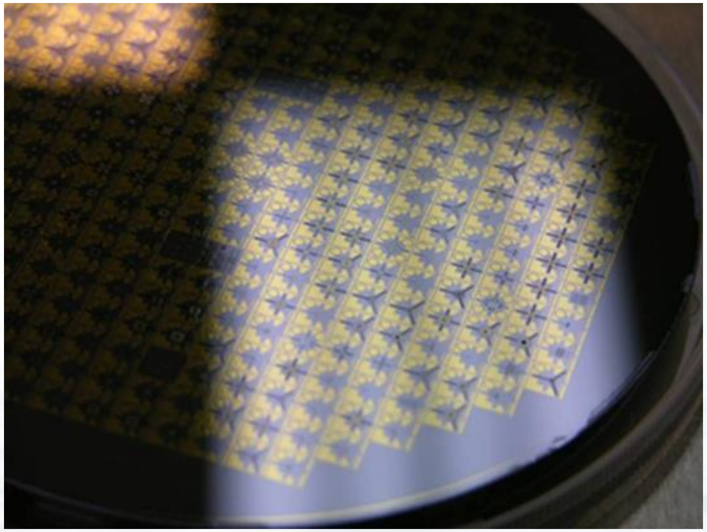
MEMS Reliability Description

Technology Goal: Assess the reliability of a microdetonator-based MEMS S&A by exposing multiple, packaged devices to simulated life cycle environments and performing subsequent failure identification and analysis in order to determine if it is capable of being utilized in a fuzing system that must meet a 99% reliability requirement.

Approach: Design, model, fabricate, and package MEMS S&A chips, expose the packages to environments determined by Mil-Std 331and JOTP-052 that represent a fuze life cycle, assess any failures, and determine cause.

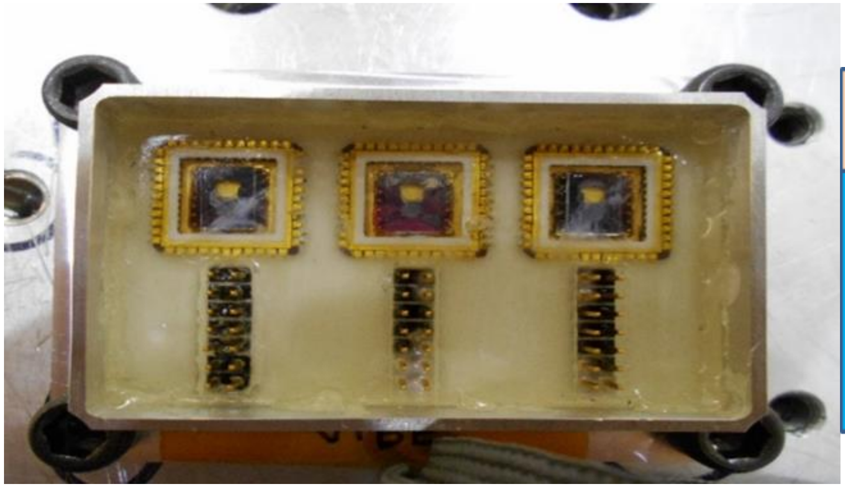


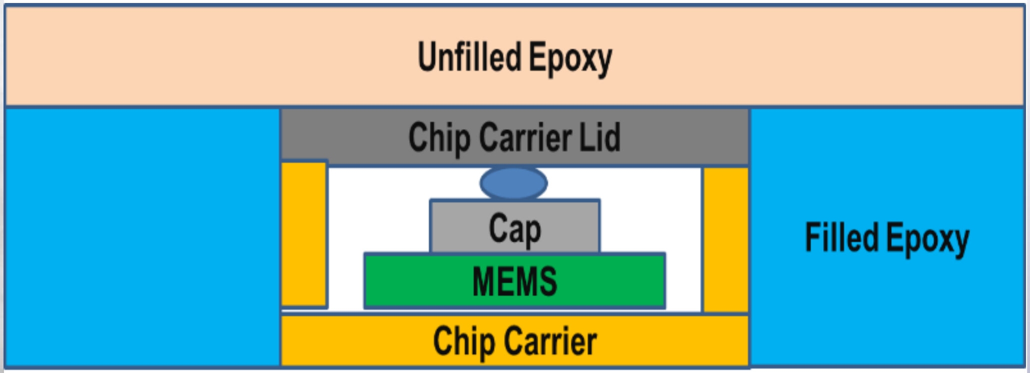
- Following work primarily funded under the Joint Fuze Technology Program

Test Matrix

Testing Purpose	Test	Results	Next Steps
Performance and Safety	T & H	Passed- No visual or electrical changes	Complete
Performance and Safety	Vibration	Passed- No visual or electrical changes	Complete
Safety	5 Foot Drop	On-going	Design and fabrication process refinements to improve subverted safety integrity
Performance	VHG	On-going	Inert and Live testing, final VHG tests will include the electronics board

Test Article Configuration





- 9 X 9 mm silicon MEMS S&A chip
  - Two of the three chips have a subverted lock (only one lock engaged)
- Wire bonded into a chip carrier (allowing for electrical interfaces through the electronics board below) for testing/functioning chip pre- and post-test
- Epoxy mixture with glass micro-balloons for shock absorption and clear mixture to allow visual inspection
- Aluminum housing fixture- represents a generic fuze housing

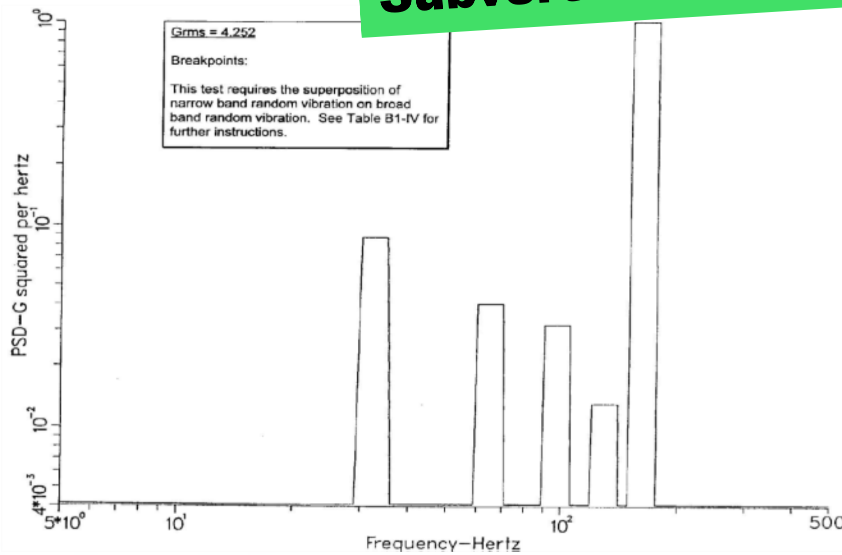
Temperature and Humidity Testing

Passed T&H Testing with No Adverse Effects to the MEMS

- Temperature/Humidity testing: Mil-Std 331-C appendix C, -54°C to 71°C and 95% humidity, cycling over 28 days
- Visually inspected MEMS and performed resistance checks pre- and post-tests
- Interesting note: unfilled epoxy (used in these tests for visual inspection) show cracks post test, while tactical micro-balloon filled epoxy seemed to be unaffected
- Johns Hopkins Applied Physics Laboratory: T&H Test Facility

Vibration Testing

Passed in Regular and Subverted Orientations



- Military tracked vehicle vibration determined to be harshest environment on MEMS S&A: Tests consisted of five phases ranging test levels from ~4-6 Grms
- Tested all five phases in X-, Y-, and Z- orientations with visual inspection and resistance checks pre- and post- testing
- Prior to test, locks were thickened to increase lock-slider interference which proved successful during these subverted tests
- Johns Hopkins Applied Physics Laboratory: Shaker Table

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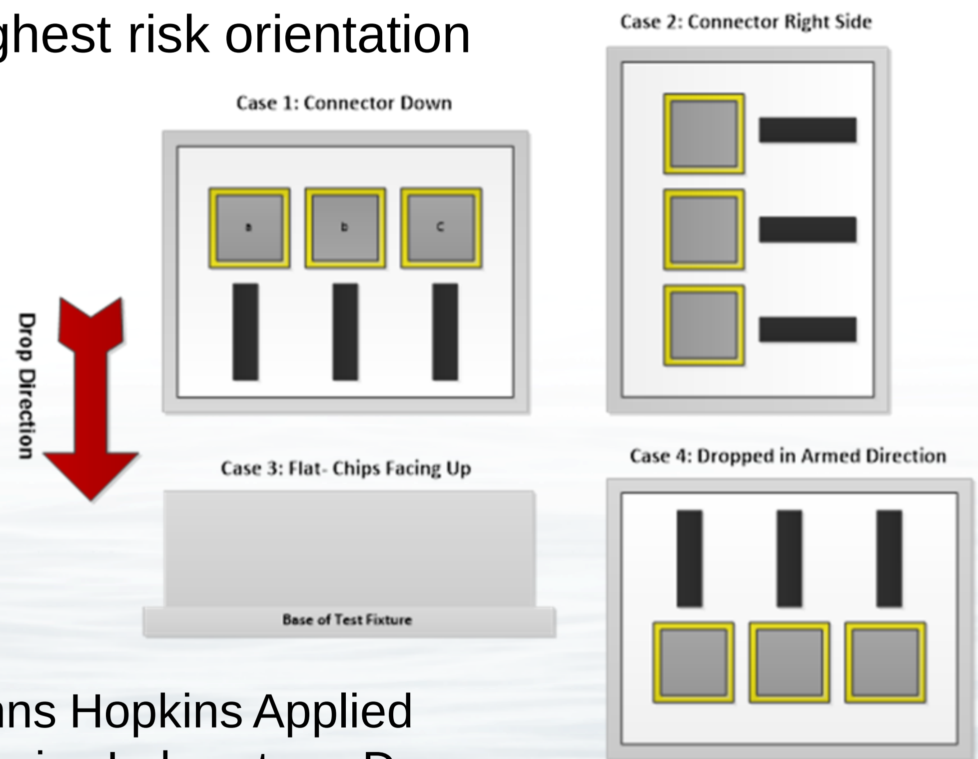
Five Foot Drop Testing

- Pass criteria: Lock re-engages post-drop so slider is kept in safe position
- Previously passed dual-lock engagement drop tests, subverted chip testing to come
- Orientation where set-back lock latches out is highest risk orientation



- Johns Hopkins Applied Physics Laboratory: Drop Apparatus

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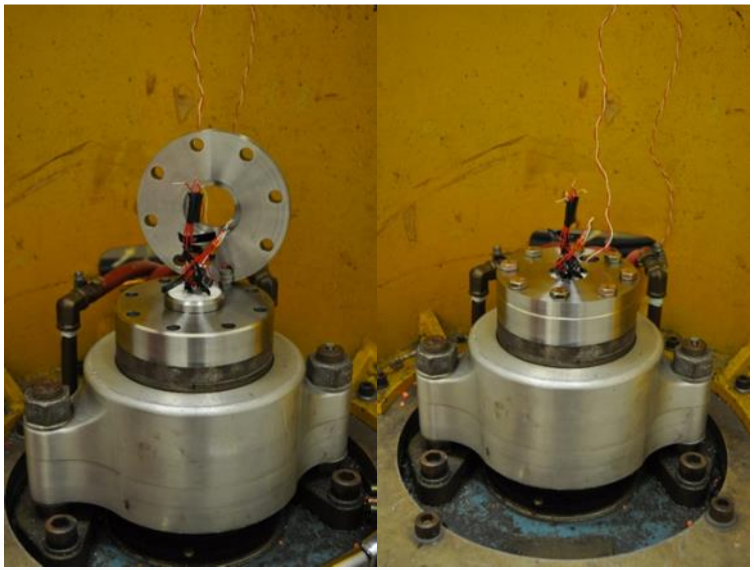
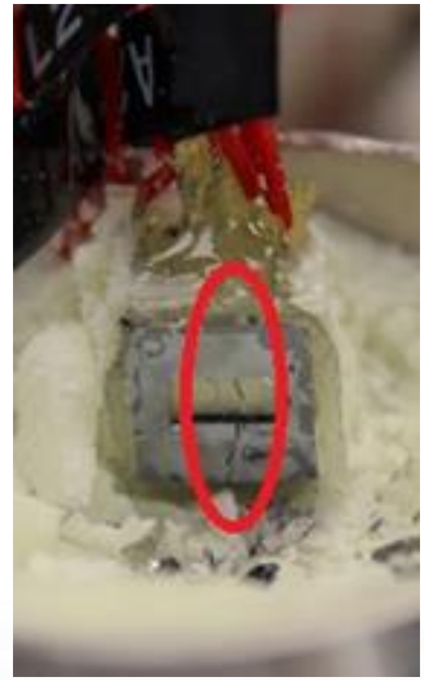
High-G Testing





- Testing is on-going with efforts to minimize limitations and maximize the effectiveness of the tests
- Naval Surface Warfare Center Indian Head Explosive Ordnance Disposal Technology Division (NSWC IHEODTD): Very High-G (VHG) Machine

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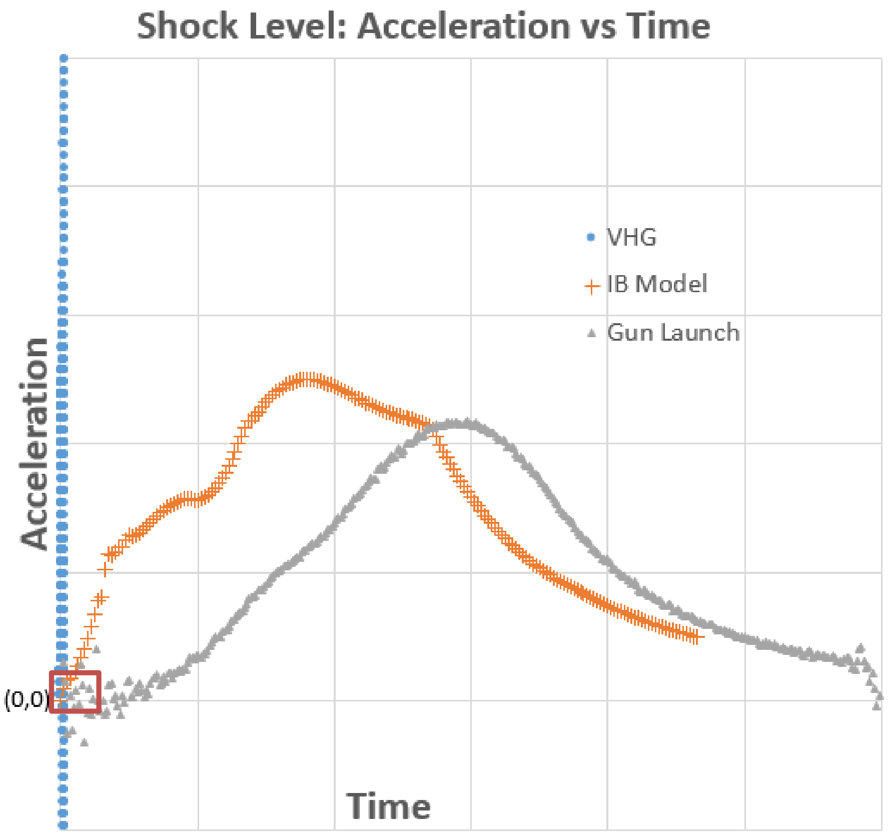
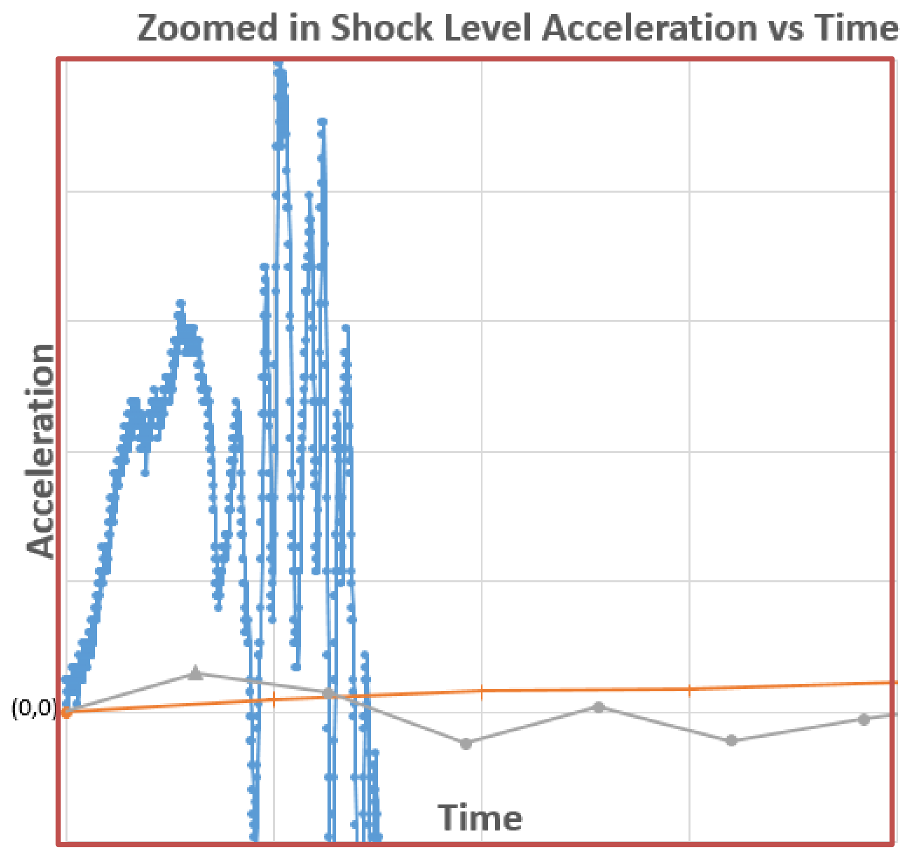
Comparison of Shock Impulses





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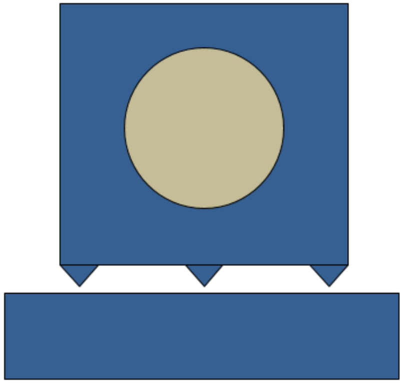
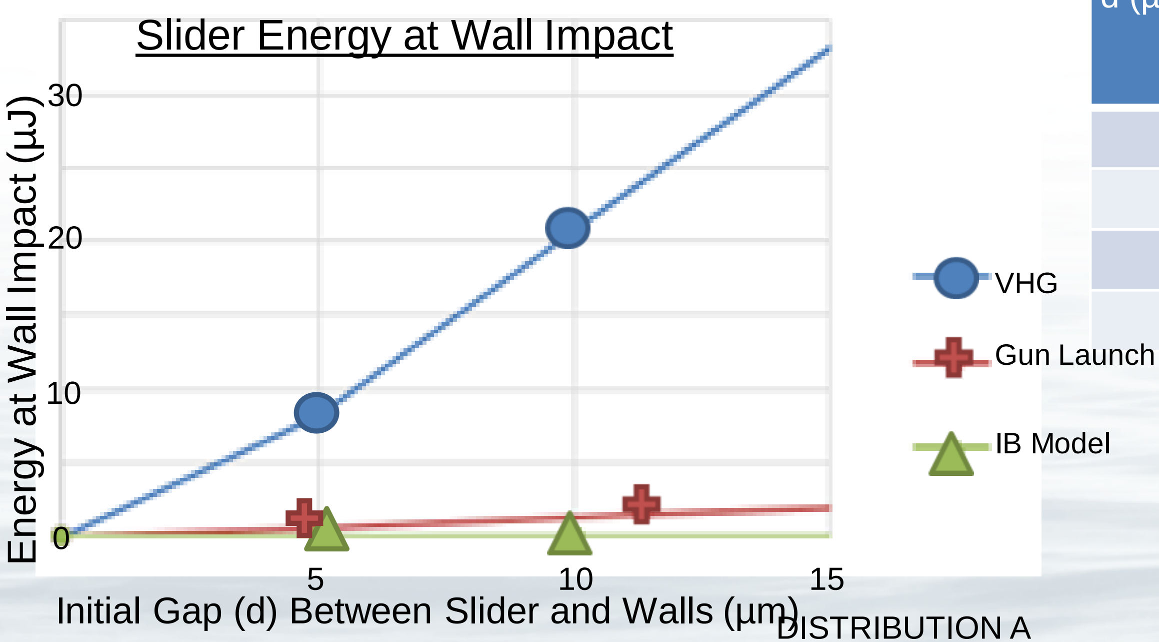
High-G Testing

- Primary damage mechanism under inertial loading is from micro structure impact
- High ramp rate from VHG results in high relative velocities between micro-structures (over-test for slider)
  - Small clearance between guides (distance= key design parameter in decreasing impact velocities)
  - High ramp rate leads to high velocity impact
  - Lower ramp rate: gap is closed before peak acceleration is reached



Distance, d (μm)	VHG Energy (μJ)	Gun Launch Energy (μJ)	IB Model Energy (μJ)
0	0	0	0
5	8.06	0.54	0.04
10	20.76	1.51	0.11
25	57.91	3.41	0.04



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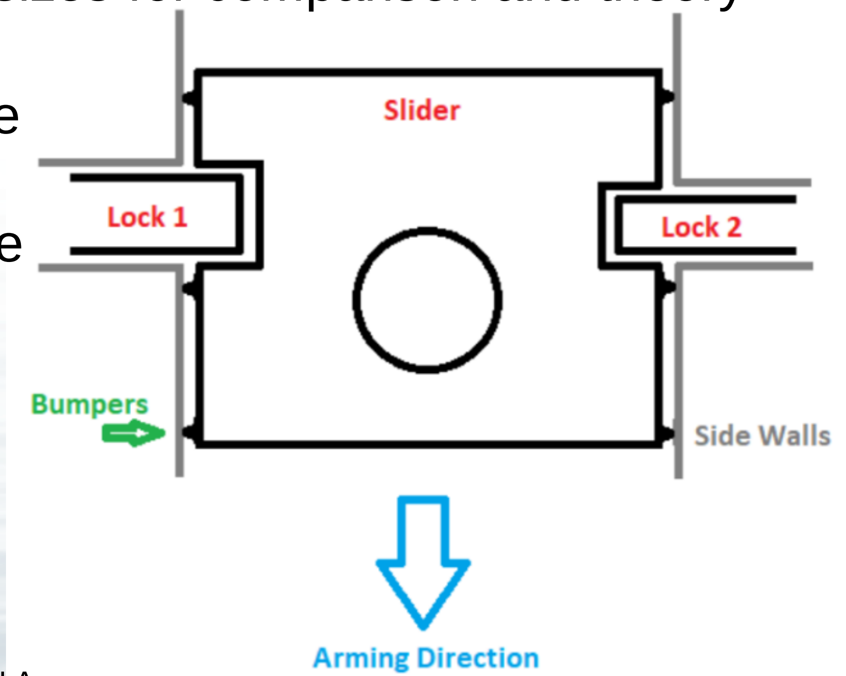
Upcoming Efforts

Drop Testing Efforts

- Conduct drop tests in various orientations with subverted chips

VHG Testing Efforts

- Refine the etching method for the slider bumpers to reduce the gap between bumpers from 30 µm to 10 µm to minimize slider impact damage.
    - Test chips with different gap sizes for comparison and theory validation.
- Refine VHG test methods to replicate damage modes of tactical shots
- Conduct VHG tests with inert and live MEMS S&A with updated testing procedures



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Conclusions

- Indian Head has been successful in T&H testing for MEMS S&A
- MEMS S&A chips have passed harsh vibration testing (tracked vehicle profiles)
- Tests are being conducted to prove MEMS S&A survivability for five foot drop
- Methods to more closely replicate gun launch shock profiles using VHG are being developed with upcoming inert and live tests to determine MEMS S&A high-G survivability

Questions?

EAS – Munitions

62nd NDIA Annual Fuze Conference
Buffalo, NY

Cost Effective and Customizable Battery Management System (BMS) for Li-Ion Batteries

May 13-15, 2019

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Agenda

- Introduction
- BMS – Common and New Features
- BMS for Flight Termination System (FTS)
- BMS Customization
- Over/Under Voltage Protection
- Over-Current Protection
- Sleep Mode
- Temperature Control
- Cell Balancing and Cell Connectivity
- Heater Functionality
- Environmental Testing

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Battery Management System (BMS) - Introduction

Lithium-Ion (Li-Ion) cells have been the predominant building block for many Li-Ion batteries in consumer electronics and in applications such as

- Vehicle traction packs
- Energy storage systems
- **Military** (focus of interest)

Li-Ion batteries perform very effectively but only if they are treated well. Therefore, they require an effective Battery Management System (BMS).

It is the job of a BMS is to ensure that the battery pack is operated safely.

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Battery Management System (BMS) - Introduction

Over the past many years of working with different BMS's for different applications, not all BMS's are the same. They must be tailored for a specific application. We developed and deployed BMS's for:

- Telecommunication industry
- Outside surveillance cameras
- Automotive
- Military (BB2590, Silent Watch, Wearable Electronics)

There are pros and cons in each applications, some features are more important than others. Even though the safety of the battery pack has always been the main concern in any application, customers also ask for a cost effective BMS without major and prolonged re-designs. Our focus in this discussion will be on **military.**

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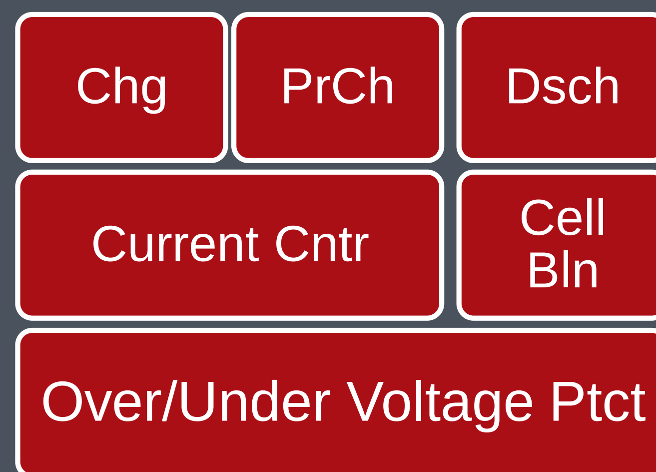
Battery Management System (BMS) – Common Features

While all BMS’s may provide:

- Over- and Under-Voltage Protections
- Perhaps Cell Balancing
- Over-current Protection
- Short Circuit Protection
- Temperature Control and Output



But, they will not tell you everything...

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Battery Management System (BMS) – New Features

Not all BMS's inform the user about a detected failure:

- What if the balancing stopped working?
- Cell Failure detection
- Sleep mode
- Can some features be turned on and off depending on the applications?

Such cost effective BMS's are not available off-the-shelf. The cost effective BMS will periodically check all its main functions and provide the status and specific alert to the user.

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Battery Management System (BMS) – Military

- Designed for and used in new Flight Termination Systems (FTS)
- Monitors and protects between 3 – 8 cells connected in series
- Supports Li-Ion -CoO2, -MnO4, -FePO4 and other chemistries
- Driven by and meets RCC-319 specification and requirements (RSO witnessed)

Comparison Table (next slide) between a good acceptable BMS and the one required for FTS Li-Ion battery per RCC-319.

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Battery Management System (BMS) – FTS

Description	Standard BMS	RCC-319
Over-voltage	Yes	Yes
Under-voltage	Yes	**No**
Over-current (charging)	Yes	Yes
Over-current (discharging)*	Yes	**No**
Short circuit protection*	Yes	**No**
Reverse Polarity	Yes	Yes
Temperature Control	Yes	Yes
Cell Balancing	Yes	Yes
Cell Connectivity Lost	Yes	Yes
Customized Alerts	Yes	**No**
Firmware*	Yes	**No**

Note:
Over-current (discharging) - No fuses allowed inside FTS batteries
Firmware - If Yes, Additional testing requires per RCC-319
External each cell voltage monitoring is available

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Battery Management System (BMS) – FTS Battery

Li-Ion FTS Battery
(Device No. G3203C1)

Performance

Voltage (V): 24 to 33.6
Current (A): 5 Discharge
1.0 Charge
Rated Capacity (Ah): 2.8 at 77ºF (25 ºC)
Internal Heater: Yes
Operating Temp. Range (F):
Charge: 32º to +113º
Discharge: -4º to +160º
Storage Temp. Range (F): <95º

Physical Characteristics

Chemistry: Li-Ion
Size: 6.26” x 3.56” x 1.34”
Weight (lb.): 2.05

Environmental

RCC319-10 FTS Battery Requirements

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Battery Management System (BMS) – Customization

How do we smoothly transition from a standard BMS to the one required for the FTS application without a major re-design?

Description	Acceptable BMS	RCC-319	Default	Versatility
Over-voltage	Yes	Yes	On	On/Off
Under-voltage	Yes	No	Off	On/Off
Over-current (charging)	Yes	Yes	On	On/Off
Over-current (discharging)*	Yes	No	Off	On/Off
Short circuit protection*	Yes	No	Off	On/Off
Reverse Polarity	Yes	Yes	Off	Always On
Temperature Control	Yes	Yes	Off	On/Off
Cell Balancing	Yes	Yes	On	Always On
Cell Connectivity Lost	Yes	Yes	On	Always On
Customized Alerts	Yes	No	On	Always On
Firmware*	Yes	No	Off	On/Off

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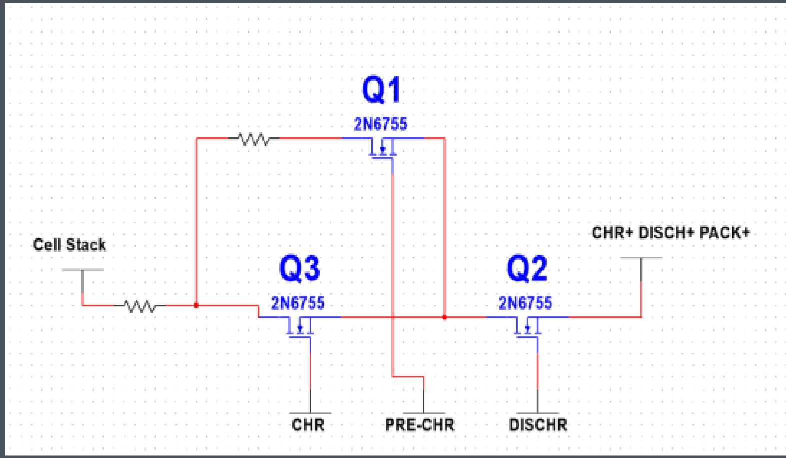
Battery Management System (BMS): Over-Voltage Protection

- Charging is performed with a 36V power supply, limiting current to 1A.
- With 8 cells connected in series, a fully charged battery would be 33.6V for LCO chemistry.
- Charging will be disabled once the battery pack voltage reaches the value specified by EAS (Currently, it is set to 33.8V)
- Discharging is enabled.



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Battery Management System (BMS): Under-Voltage Protection

- Due to RCC-319, there is no under-voltage protections permitted during discharge. Also, there are no fuses. Traces are sized for 10A of continuous discharge current.
- However, the BMS can be implemented as a charger with the under-voltage protection enabled. Therefore, the low voltage cut-off would be 24V for the LCO chemistry.

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Battery Management System (BMS): Over-Current Protection

The charge and discharge current are monitored on high side all the time, except during the sleep mode.

The BMS has different current threshold (and time) depending on application. Thresholds are set by EAS.

- Over-Current condition (Charging) – Example, multiple batteries connected in parallel
- Over-Current condition (Discharging) – Example, fuse clearing in Telecommunication
- Short Circuit condition (Discharge) – Example, external short
- Charge and Discharge paths can be separated. Currently, set as one path
- Pre-charge control possible. Designed with the intent to use during charging at cold temperature

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Battery Management System (BMS): Sleep Mode

- The battery pack goes into the sleep mode if there has been no current flow for a certain period of time. That time duration is set by EAS.
- Sleep mode condition adds **prolonged storage** of the batteries. The re-charge can be done once a year instead of every 6 months (typical).
- The battery gets out of sleep mode immediately once a charger is connected or a current flow is detected (wake-up condition).

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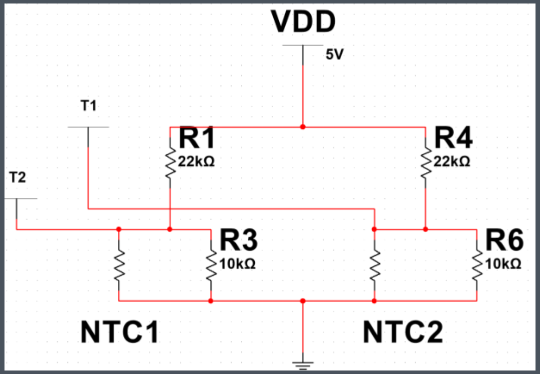
Battery Management System (BMS): Temperature Control

- One RTD for external use. It is physically placed on the cell #4.
- Two thermistors for internal BMS use. They can be used to monitor FET temperature, battery pack temperature or additional cell temperature.
- Over-temperature condition is set by EAS. The battery pack would shut down if the over-temperature condition is detected.
- Normal condition will return once the condition is cleared. Currently, this feature is not used. It can be enabled at any time, or when used as a charger.



+80C	0.15V
+50C	0.29V
+25C	0.46V
0C	0.62V
-20C	0.71V
-40C	0.75V

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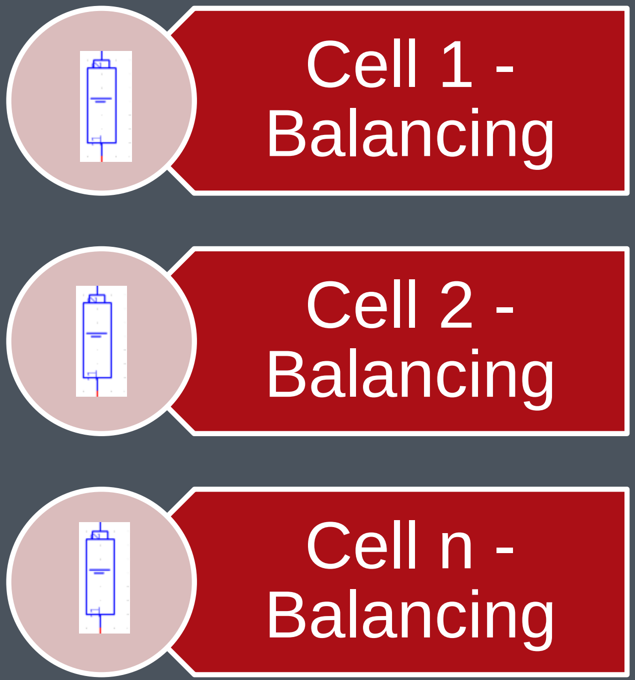
Battery Management System (BMS): Cell Balancing

- Each cell balancing FET turns automatically once the cell voltage reached 4.2V (LCO chemistry). This voltage can be changed by EAS depending on the cell chemistry used

- It is passive balancing. Balancing resistors are sized to sink 100 mA of current

- Balancing stops when the cell voltage drops below 4.2V (LCO chemistry)



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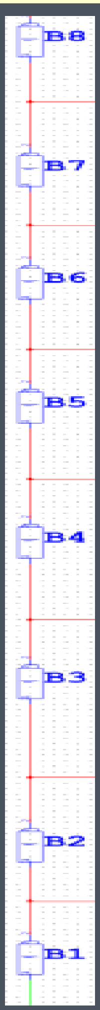
Battery Management System (BMS): Cell Connectivity Lost

- As an additional safety feature, Cell Connectivity (Open-Wire) detection has been implemented. The main goal of this feature is to turn off the power FETs if there is an open wire to prevent the cells being excessively charged or discharged.

- Over-voltage and under-voltage protection will not detect if cell balancing has been compromised. Therefore, cell(s) can still be damaged despite over-voltage and under-voltage protections functioning properly.

- Cell Connectivity (Open-Wire) detection checks connectivity of the cell to the balancing circuitry and checks balancing FETs connectivity.



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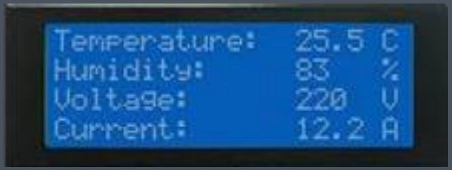
Battery Management System (BMS): Customized Alerts

At the battery level, there are no visual alerts (i.e. LEDs, displays). There is RS-485 output for the external charger/analyzer. The external charger would have customized visual indicators for as many or as little alerts as desired. Current design would have an LED indicating the following events:

- Battery charging and discharging
- Battery pack shutting down
- Open-wire detection
- Over-current protection, Over-, Under-voltage protection
- Over-temperature protection
- More alerts can be easily implemented



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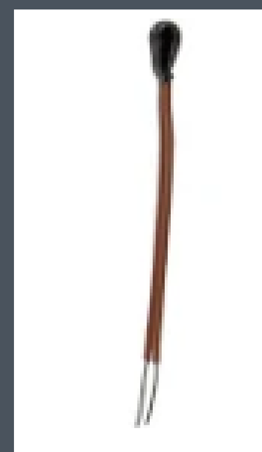
Battery Management System (BMS): RTD Output

Precision RTD output mounted on the cell #4. This output is used during flight:

A sample is listed below:

- 1,236 Ohms for 61 degrees C
- 1,097 Ohms for 25 degrees C
- 1,020 Ohms for 5 degrees C
- 961 Ohms for -10 degrees C
- 882 Ohms for -30 degrees C
- 843 Ohms for -40 degrees C



- Cell 1
- Cell 2
- Cell 3
- Cell 4 +RTD
- Cell 5
- Cell 6
- Cell 7
- Cell 8

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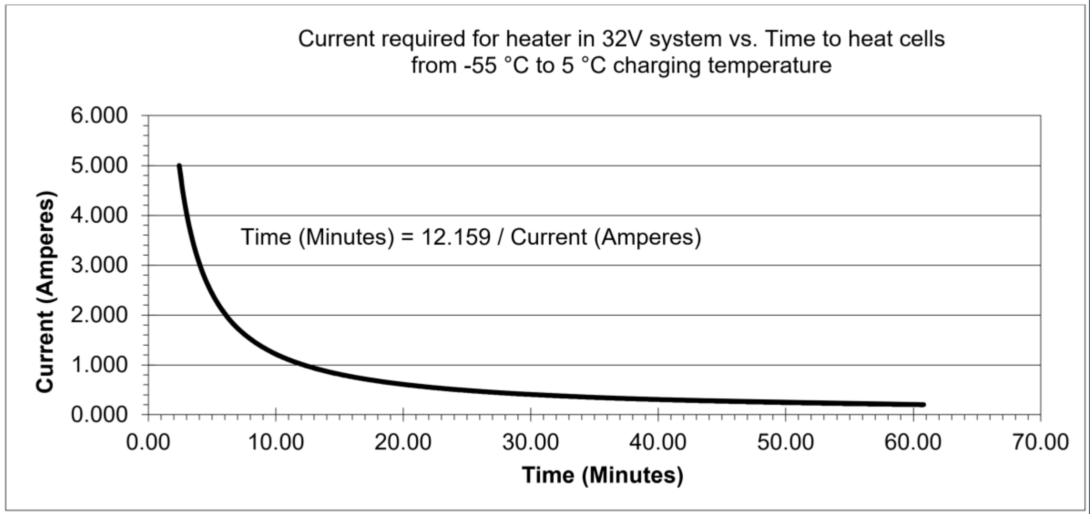
Battery Management System (BMS): Heater Functionality

Battery BMS has an integrated heater for cold discharge applications:

- EAS programs the desired On and Off temperatures
- Automatic On/Off switching
- Requires external power supply (32V, 16W)



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Battery Management System (BMS): Charger/Analyzer

Because of the flexibility and versatility of the BMS in the Li-Ion battery, the board can be easily integrated into a portable charger. All the important features for the charger can be easily enabled:

- Plot of each cell voltage
- Plot of the total battery voltage
- Current flowing in and out of the battery
- RTD measurement

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Battery Management System (BMS): Environmental Testing

BMS boards passed various vibrations and shock testing up to 10db as part of the FTS battery qualification at hot and cold extremes:

- Board did not crack or break
- Components on the boards did not crack or break
- No signs of fatigue or failures

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Battery Management System (BMS): Questions

- **Questions?**
- **Thank you for your attention!**